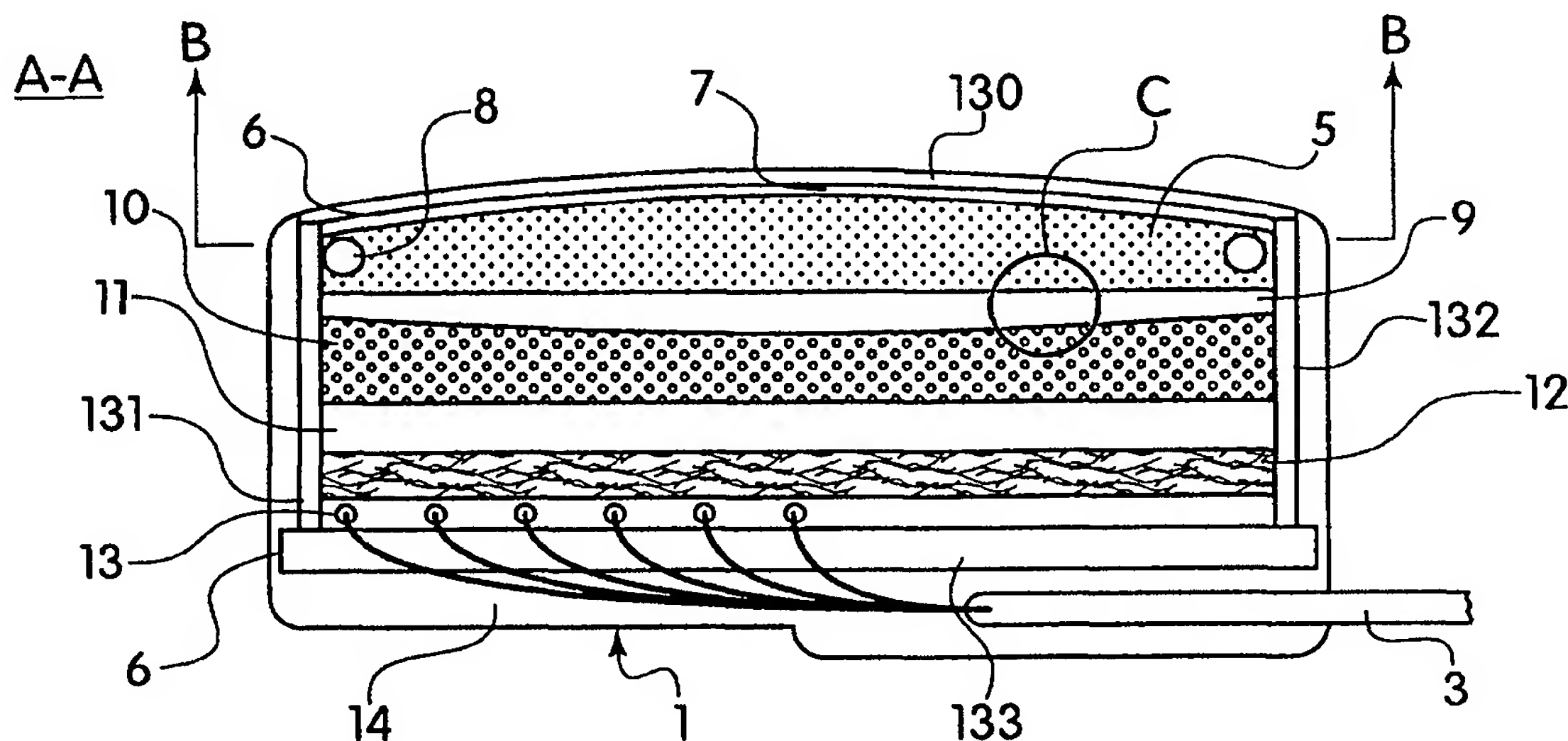




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<b>(21) International Application Number:</b> PCT/US99/27104 <b>(22) International Filing Date:</b> 12 November 1999 (12.11.99) <b>(30) Priority Data:</b> 09/193,555                      17 November 1998 (17.11.98)      US <b>(71) Applicant:</b> SAMALON TECHNOLOGIES [US/US]; 80 Essex Avenue East, Avenel, NJ 07001 (US). <b>(72) Inventors:</b> SAADIA, Sammy, M.; 395 Wells Avenue, Oakhurst, NJ 07755 (US). MATALON, Michael, R.; 2216 Avenue K, Brooklyn, NY 11210 (US). LERNER, Robert, A.; 288 Bay 38th Street, Brooklyn, NY 11214 (US). <b>(74) Agent:</b> ABELEV, Gary; Kenyon & Kenyon, One Broadway, New York, NY 10004 (US).		<b>(81) Designated States:</b> AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>

(54) Title: SYSTEM AND METHOD FOR PROVIDING A DENTAL DIAGNOSIS



## (57) Abstract

An intra-oral sensor (1) is provided for a dental diagnosis. The sensor includes an arrangement receiving an external signal and converting (5) the external signal into a light beam. The sensor further includes a light reflecting layer (7) and a light concentrating element (9) concentrating the light beam into the concentrated light beam. A particular layer (10) (e.g., a Charge Couple Device ("CCD") or Complementary Metal-Oxide Semiconductor ("CMOS") array) receives the concentrated light beam and converts the concentrated light beam into an analog signal. A calibrating procedure is also provided. An internal light device (8) of the sensor is activated to generate a light signal. Then an amplification level of an amplifier of the intra-oral sensor is adjusted as a function of a predetermined correction value. The light signal is detected and converted into the digital signal as a function of the adjusted amplification level.

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## SYSTEM AND METHOD FOR PROVIDING A DENTAL DIAGNOSIS

### FIELD OF THE INVENTION

The present invention relates to system and method for providing a dental diagnosis.

### 5 BACKGROUND INFORMATION

To efficiently treat a patient, it is necessary for a dentist to accurately and quickly determine a dental diagnosis. The dental diagnosis can be determined using information about a condition of the patient's mouth (e.g.,  
10 teeth, gums, oral cavity, etc.). Such information may be obtained using a conventional dental film technology. The dental film technology utilizes an X-ray apparatus and expensive chemicals for developing a dental film. However, the dental film technology is time and labor consuming. In  
15 addition, the dental film has a low sensitivity which requires the dentist to increase and/or repeat an application of an X-ray radiation (e.g., in case of the dental film's failure). Consequently, the patient is exposed to unnecessary doses of the X-ray radiation and there is an unproductive loss of time  
20 for the dentist and the patient.

There is now trend is to use a digital radiography system, such as the one described in U.S. Patent No. 5,434,418. This conventional digital radiography system uses a charge coupled device ("CCD") and a sensor. However, this  
25 system does not capture a comprehensive picture of the condition of patient's teeth because it uses only an X-ray technique to obtain its information.

To produce a satisfactory image, the sensor should be calibrated. Such calibration requires an activation of the  
30 X-ray apparatus and exposure of the patient to the X-ray radiation. In some cases, the calibration must be repeated a number of times until the satisfactory image can be developed. However, the patient would again be exposed to the X-ray radiation. In addition, there would be an unnecessary loss of  
35 time for the dentist and for the patient.

U.S. Patent No. 5,331,166 describes an automatic control system which controls the X-ray radiation using detecting elements. These detecting elements are located in the sensor which measures a value of a signal having a particular X-ray intensity. However, this control system does not prevent the unnecessary X-ray radiation received by the patient. In addition, this conventional procedure is not safe because it is executed during an activation of the X-ray apparatus.

U.S. Patent No. 5,434,418 describes an intra-oral sensor which uses a plurality of glass fiber bundles to transfer a light signal from a scintillator surface to a CCD. However, a level of the signal is reduced due to high complexities in retaining a quality optical contact between the surface of the scintillator crystal and the CCD. In addition, areas of conjugation at the surfaces of the scintillator crystal and the CCD are not equal. Thus, the process described in this U.S. Patent creates additional losses in the light signal, which may result in an unnecessary increase of X-ray radiation exposure.

U.S. Patent No. 5,723,865 describes another X-ray apparatus in which the light signal from the scintillator is transferred to the CCD using an imaging lens. However, technical parameters and dimensions of this conventional X-ray apparatus do not enable its use for intra-oral dental applications.

U.S. Patent No. 5,691,539 describes a conventional intra-oral X-ray sensor which has a rectangular housing. An electrical cable with a connector is joined to a back portion of the housing coupled to an image processing unit. However, such design is extremely uncomfortable for the patient because its shape does not conform to a dental arch and a natural jaw curve of the patient. In addition, long cables from the sensor to the image processing unit irritates the patient and is inconvenient for the dentist and the patient.

A conventional intra-oral camera system, e.g., AcuCam® Concept III by Dentsply New Image, has a diagnostic capability and is capable of serving as an educational tool. The intra-

oral camera system may analyze a cavity of a mouth to produce video images. However, an application of this intra-oral camera system requires an additional equipment connected to the X-ray apparatus. Furthermore, the video images produced by this conventional intra-oral camera system cannot be browsed nor compared with other images produced using different hardware elements and/or software modules.

#### SUMMARY OF THE INVENTION

The present invention relates to an intra-oral sensor for providing a dental diagnosis. The sensor includes an arrangement receiving an external signal and converting the external signal into a light beam. The sensor further includes a light reflective layer and a light concentrating element (e.g., a lens) concentrating the light beam into the concentrated light beam. A particular layer (e.g., a Charge Coupled Device ["CCD"] or Complementary Metal-Oxide Semiconductor ["CMOS"] array) receives the concentrated light beam and converts the concentrated light beam into an analog signal. In addition, the sensor includes an electronic circuitry converting the analog signal into a digital signal, the digital signal providing data for the dental diagnosis.

The present invention also relates to a method for providing the dental diagnosis. An internal light device is activated to generate a light signal. Then an amplification level of an amplifier of the intra-oral sensor is adjusted as a function of a predetermined correction value. The light signal is detected and converted into the digital signal as a function of the adjusted amplification level. If the internal light device is activated, then if a signal value of the digital signal is not equal to a predetermined reference level, then the predetermined correction value is modified as a function of the predetermined reference level and the signal value until the signal value is equal to the predetermined reference level. The digital signal provides data for the dental diagnosis.



BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows an exemplary embodiment of a system providing a dental diagnosis according to the present invention.

5 Figure 2 shows a block diagram of an exemplary embodiment of an electronic arrangement provided in a computing device of the system.

10 Figure 3a shows a prospective view of an exemplary embodiment of a sensor according to the present invention utilized with the system illustrated in Figure 1.

Figure 3b shows a left side view of the sensor illustrated in Figure 3a.

15

Figure 3c shows a front side view of the sensor illustrated in Figure 3a.

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Figure 3d shows a top view of the sensor illustrated in Figure 3a.

Figure 4a shows a prospective view of an alternative exemplary embodiment of the sensor according to the present invention which has coatings.

25

Figure 4b shows a left side view of the sensor illustrated in Figure 4a.

30

Figure 4c shows a front side view of the sensor illustrated in Figure 4a.

Figure 4d shows a top view of the sensor illustrated in Figure 4a.

35

Figure 5 shows an exemplary embodiment of a cable-retractable device according to the present invention which may be coupled to the sensor illustrated in Figures 3a-3d and 4a-4d.

Figure 6a shows a cross-section view of an exemplary embodiment of the sensor taken along line A-A as illustrated in Figures 3a and 4a.

5 Figure 6b shows a cross-section view of an alternative exemplary embodiment of the sensor taken along line A-A as illustrated in Figures 3a and 4a.

10 Figure 7a shows an enlarged view of a section of the sensor taken in an exemplary area C illustrated in Figure 6a.

Figure 7b shows an enlarged view of a section of the sensor taken in an exemplary area D illustrated in Figure 6b.

15 Figure 8 shows a top view of a light sensitive array of the sensor taken along line B-B as illustrated in Figures 6a and 6b.

20 Figure 9a shows a block diagram of an exemplary embodiment of an electronic arrangement of the sensor according the present invention illustrated in Figures 6a and 6b.

25 Figure 9b shows a block diagram of another exemplary embodiment of the electronic arrangement of the sensor according the present invention illustrated in Figures 6a and 6b.

30 Figure 10a shows a first exemplary flow chart illustrating a method according to the present invention.

Figure 10b shows a second exemplary flow chart illustrating the method according to the present invention.

35 Figure 10c shows a third exemplary flow chart illustrating the method according to the present invention.

Figure 11a shows a graph illustrating a coefficient of

amplification for an amplifier of the sensor according to the present invention.

Figure 11b shows another graph illustrating a reference level of the internal light signal for the amplifier as a function of time.

Figure 12 shows an exemplary table for analyzing an incoming signal using a remote digital unit.

#### DETAILED DESCRIPTION OF THE INVENTION

Figure 1 shows an exemplary embodiment of a system 100 according to the present invention. The system 100 allows a user (e.g., a dentist or a dental assistant) to obtain a comprehensive information about patient's mouth in a safe, expedient and convenient manner. A preferred embodiment of the system 100 includes an intra-oral sensor 1, a remote digital unit ("RDU") 18, an external signal device ("ESD") 34 and a computing device 22. The ESD 34 may be, e.g., an X-ray apparatus or an Infrared apparatus. In an alternative exemplary embodiment, the system 100 may also include a video apparatus and/or an audio apparatus to record an examination of the patient. The audio apparatus may be positioned inside or outside of the system 100. A plurality of the systems 100 may also be coupled together to form a dedicated network (e.g., a local area network or a wide area network). The system 100 may further be connected to a communication network (e.g., the Internet).

A brief summary of an exemplary operation of the system 100 according to the present invention is as follows. The sensor 1 is calibrated using an Internal Light Device 8 ("ILD") which is provided inside the sensor 1. After calibrating the sensor 1, the ILD 8 is deactivated and the ESD 34 is activated. The ESD 34 generates an external signal (e.g., an X-ray radiation, an Infrared emission, etc.) which is detected by the sensor 1 and converted into a digital signal. This digital signal is then provided, via an electrical cable 3, to



the RDU 18. The RDU 18 determines a type of an apparatus that is transmitting the digital signal and then forwards the digital signal to the computing device 22 for processing (e.g., displaying on a display device, etc.). Details of this operation are described below.

Figure 2 shows an exemplary embodiment of the computing device 22 (e.g., a personal computer). The computing device 22 may include an input device 28, an output device 30, a controller 26, a memory unit 23, a first interface unit 27 and a second interface units 29. The above-described elements of the computing device 22 are connected to a bus 31. The input device 28 may include, e.g., a keyboard, a keypad, a scanner, a disk drive (e.g., floppy, CD or DVD), a voice recognition device, etc. Using the scanner, the user may be able to scan images from a film into the memory unit 23 in order to store a complete patient record in a digital form. The output device 30 may include, e.g., a high-resolution display, a printer, a disk writer, a projector and/or another conventional output device. The first interface unit 29 facilitates a connection between the computing device 22 and the RDU 18, and the second interface unit 27 facilitates a connection between the computing device 22 and at least one of the dedicated network and the communication network.

Figures 3a-d show a first exemplary embodiment of the sensor 1 according to the present invention. The sensor 1 has a preferably flat-convex shape which is designed to fit natural contours of the patient's mouth and teeth. One of the advantages of such shape is that it allows a deep and tight reach into subgingival areas as a parallel orientation is assumed. In another exemplary embodiment, the sensor 1 has a rectangular shape, however other shapes are also conceivable (e.g., square, circular, oval, etc.).

The sensor 1 has the case 14 and an edge portion 1A disposed thereon. The case 14 hermetically encloses the elements of the sensor 1. The case 14 is composed of a soft and force-absorbent material (e.g., a thermosetting hygienic protective rubber material) so that the sensor 1 would not be

damaged if the patient applied pressure on the sensor 1. The edge portion 1A is preferable situated on a side of the case 14 and is also composed of a soft material. The material of the edge portion 1A is softer than the material of the case 14 and can include a sponge-like material. The sponge like material would protect the patient's mouth against scratched and/or abrasions which may occur otherwise during the use of the sensor 1. The case 14 provides a rugged, shatterproof finish which is immune to a shock and/or a bite of the patient. A top wall of the case 14 is composed of a material which allows the external signal to pass therethrough. Other walls of the case 14 are composed of a material absorbing the external signal (e.g., the material including an additive of lead, tungsten and/or bismuth).

Since a sterilization process of the sensor 1 requires utilization of a high temperature, the sensor 1 is not autoclaved to prevent negative effects of such high temperature on a particular layer 10 (e.g., a CCD array or a CMOS array). Therefore, the sensor 1 may utilize a custom fitted plastic sheaths or a disposable latex coating for an infection control.

Figures 4a-d shows a second exemplary embodiment of the sensor 1' according to the present invention. The sensor 1' of the second embodiment has identical elements as described above for the sensor 1 of the first embodiment. In addition, this sensor 1' has at least one (preferably 2 or 4) coating 121 situated preferable at corners of a housing 6 of the sensor 1'. This coating 121 includes a filler material which is composed mostly of a softly protective material (e.g., polypropylene or polyethylene). The filler material is an inert granular material being composed of small particles which are mixed into a plastic material prior to molding. One of advantages of the coating 121 is that it further protects the tender tissue of the mouth from any damage. In addition, the coating 121 may include a sterile material such as polyvinyltoluence and/or methacrylate-styrene copolymers. These materials are self-sterilizing and may include an anti-

microbial solution.

The sensor 1 is coupled, via the electrical cable 3, to a connecting plug 4. Figure 5 shows a detailed illustration of the connecting plug 4 which may be coupled to the RDU 18 and/or to the computing unit 22. The connecting plug 4 includes a cable-retractable device ("CRD") 2 which allows the user to retract the electric cable 3 within a housing 120 of the connecting plug 4. In an alternative exemplary embodiment according to the present invention, a circuit interface unit 21 of the sensor 1 may include a wireless remote unit ("WRU") (not illustrated) instead of the connecting plug 4 and the electrical cable 3. This WRU may transmit the signal (e.g., a radio-frequency signal) to the RDU 18 and/or to the computing device 22. Thus, the RDU 18 and/or the first interface unit 26 of the computing unit 22 may also include the WRU.

Figure 6a shows a cross-sectional view of the sensor 1, taken along line A-A as illustrated in Figures 3a and 4a. The sensor 1 includes the water-resistant housing 6 enclosed by a case 14. Inside of the housing 6, at least one internal light device ("ILD") 8 is situated within a crystal 5 (i.e., a converting element). Figure 7a shows an exemplary area C of the sensor 1 where a light concentrating element (e.g., a micro lens, a concentric lens [see, e.g., Figures 6b and 7b], etc.) 9 is situated between the crystal 5 and the particular layer 10. The particular layer 10 is situated on a top layer 11 which is attached to a silicon substrate 12. A plurality of pins 13 are positioned below the silicon substrate 12 and are coupled to the electrical cable 3.

The crystal 5 is capable of converting the external signal into a corresponding light beam. When exposed to the X-ray radiation as the external signal, the crystal 5 is configured as a scintillator which is composed of a single optically transparent mono crystal (e.g., CsI(Tl) or NaI(Tl)). In an alternative exemplary embodiment at least one of the crystal 5 and the particular layer 10 may be composed of CdTe(Cl). The crystal 5 preferably has a predetermined shape (e.g., a flat shape at a bottom portion of the crystal 5 and a

convex shape at a top portion of the crystal 5) and a predetermined thickness (e.g., no more than 500 micron). When the external signal (i.e., the X-ray radiation having an energy of 70 KeV) is generated and recorded by the sensor 1, the crystal 5 emits the corresponding light beam which is proportional to the intensity of the external signal.

When using the Infrared emission as the external signal, the crystal 5 is preferably composed of a thermo-illuminating material and converts the external signal (i.e., the Infrared emission) into the light beam. A light reflective layer 7 of the sensor 1 includes an Infrared transparent light concentrating element composed of silicon and/or germanin.

As discussed above, the top portion of the housing 6 has a convex shape. It is preferable for a top portion of the sensor 1 to be tightly pressed to the teeth. The convex shape, which follows the natural curve of the jaw, may increase a quality of the image.

In an advantageous embodiment of the sensor 1 according to the present invention, the housing 6 (which situates the crystal 5 therein) has a light-opaque feature. In particular, the housing 6 prevents the external signal from entering or exiting the housing 6 on sides 131-135 (shown in Figures 6a, 6b and 8) of the housing 6. However, at a top side 130 of the housing 6, the external signal can enter the housing 6, but not exit. The top side 130 is preferably positioned, as shown in Figure 6a, above the crystal 5.

The light reflective layer 7 of the housing 6 which is situated on an internal side of the top side 130, as shown in Figure 5a. The light reflective layer 7 is composed of, e.g., silver or aluminum. The light reflective layer 7 is capable of completely reflecting the light beam emitted by the crystal 5. Thus, a surface of the light reflective layer 7 does not allow the light beam to be dissipated by the crystal 5 in different directions, and concentrates the light beam toward the particular layer 10 (e.g., toward matrix light sensitive elements of the CCD array or the CMOS array). The light reflective layer 7 has a thickness of preferably no more than

30 micron; however, other thicknesses are conceivable.

The ILD 8 of the sensor 1 is utilized to calibrate the system 100 by providing the light beam which is representative of a standard value (e.g., a predefined value) of illumination. The ILD 8 is provided within the crystal 5 and is positioned along one of the second and third sides 131, 132 of the housing 6, below the first side 130. The ILD 8 may include at least one light emitting diode (e.g., preferably two, four, six, eight, etc.). In a preferred exemplary embodiment according to the present invention illustrated in Figures 6a, 6b and 8, two ILDs 8 are situated opposite one another along a horizontal symmetry axis X-X.

The light concentrating element 9 preferably includes a flat-convex converging micro-lens which provides a high quality optical contact between the crystal 5 and the particular layer 10. The light concentrating element 9 operates as a magnifier to magnify the light beam emitted from the crystal 5 and to improve a contrast sensitivity and details of the image. To exclude an undesirably scattering external signal on the particular layer 10, the light concentrating element 9 is composed of a highly absorbing material which absorbs the scattered external signal and does not generate a secondary exposure (e.g., a secondary scale of radiation). Such material may be, e.g., a glass material or a plastic material, with an additive material (e.g., lead, tungsten and/or bismuth).

An alternative exemplary embodiment of the sensor 1 according to the present invention is shown in Figures 6b and 7b. In this embodiment, the light concentrating element 9 has a flat shape. Such a flat shape allows the sensor 1 to be thinner and more comfortable for the patient. As shown in Figure 7b, the light concentrating element 9 has a concentric relief 140 (i.e., a surface) for concentrating the light beam, which has a preferably stepped shape.

As described above, the particular layer 10 is utilized to convert the light beam into an analog signal. The particular layer 10 may include the CCD and/or the CMOS matrix



of the light sensitive elements as shown in Figure 8.

The bottom layer 11 includes an electronic integrated circuit 150. Figure 9a shows an exemplary embodiment of this electronic integrated circuit 150. The circuit 150 may include a programmable, low-noise amplifier 15, a peak comparator 16 (which establishes a threshold level), an analog-to-digital converter ("A/D") 17, a digital-to-analog converter ("D/A") 19, a memory unit 20 and a circuit interface unit 21. Functions of these elements of the circuit 150 are described below.

An alternative exemplary embodiment of the sensor 1 may include at least one controller 32 shown in Figure 9b. This controller 32 may perform all necessary operations to calibrate and utilize the system 100 without requiring the use of the computing device 22. The controller 32 is, preferably, positioned inside of the sensor 1; alternatively, the controller 32 may be positioned outside of the sensor 1. In particular, an alternative embodiment of the system 100 according to the present invention may include the sensor 1 having the above-described controller 32, the RDU 18, the ESD 34 and the output device 30.

A detailed exemplary operation of the system 100 according to the present invention is shown in Figures 10a-10c. Figure 10a shows a first exemplary flow chart of the method according to the present invention. A reference level RL and a prime value K (e.g., a coefficient of amplification for the sensor 1) may be preset (steps 905 and 910) by a manufacturer of the sensor 1 and/or by the user. In an exemplary embodiment, the reference level RL and the prime value K may be stored in the memory unit 20 of the sensor 1 and may be reset each time the system 100 is activated. Alternatively, the reference level RL and the prime value K may be stored in the memory unit 23 of the computing device 22. The computing device 22 transmits the reference level RL and the prime value K to the sensor 1 when the system 100 is activated or when the user desires to do so.

The threshold level remains in the memory unit 20. The

comparator 16 establishes the threshold level which is higher than a signal-to-noise ration of the particular layer 10 (e.g., a dark current shown in Figure 11B). Then, the user activates the ILD 8 (step 915). An amplification level of the amplifier 15 is adjusted as a function of the prime value K (step 917).

The ILD 8 generates the light beam within the crystal 5. The light concentrating element 9 focuses the light beam onto the particular layer 10. The particular layer 10 detects the light beam as an analog signal (step 920) and the amplifier 15 amplifies this analog signal. Subsequently, the comparator 16 filters the analog signal using the value of the threshold level; only relevant part of the analog signal (i.e., a portion which has the optimal signal-to-noise ration shown in Figure 11b) passes through the comparator 16. This portion of the analog signal is converted into the digital signal using the A/D convertor 17 (step 925). The digital signal is transmitted to the RDU 18 via the circuit interface unit 21. The RDU 18 forwards the digital signal to the computing device 22.

The computing device 22 determines whether the ILD 8 (or the ESD 34) is activated (step 930). If the ILD 8 is activated, that indicates that the system 100 is in a calibration (i.e., testing) mode and the digital signal is the ILD signal. Thus, the computing device 22 may display the image which is representative of the ILD signal on the output device 30 (step 935). A value of the digital signal is then compared to the value of the reference level RL (step 940).

If the value of the digital signal is not equal to the value of the reference level RL as shown in Figure 11b, then the prime value K must be adjusted (see a value  $K_1$  and a value  $K_2$  in Figure 11a). The computing device 22 adjusts the prime value K as a function of the value of the digital signal and of the value of the reference level RL (step 945). The prime value K is transmitted back to the sensor 1 via the RDU 18 and stored in the memory unit 20 of the sensor 1. The steps 917-945 are repeated until the digital signal is equal to the

value of the reference level RL.

When the digital signal is equal to the value of the reference level RL (in step 940), the calibration mode is completed and the system 100 is ready to initiate an execution mode (step 950). The user deactivates the ILD 8 and activates the ESD 34 (step 955) which generated an ESD signal (e.g., the X-ray radiation or the Infrared emission). The amplification level of the amplifier 15 is then adjusted as a function of the prime value K (step 917).

Therefore, the ESD signal is detected and converted into the light beam using the crystal 5. This light beam is converted into the analog signal using the particular layer 10 and the amplifier 15 (step 920). The analog signal is converted into the digital signal (step 925) using the A/D converter 17. Since the ILD 8 is not activated (step 930), that the system 100 is not in the calibration mode. Therefore, the image which is representative of the ESD signal may be stored and/or displayed (step 960) using the output device 30. In particular, the output device 30 may facilitate a storage of the digital signal by printing the image using the printer, by storing the image on a CD ROM disk or in a memory storage unit of a network server, or by transmitting the image to a predetermined location via the communication network.

In a second exemplary embodiment of the method according to the present invention shown in Figure 10b, the user can also bypass the calibration mode (step 936). In particular, if the calibration mode is desired, the user may calibrate the system 100 manually or automatically (step 937). If the manual calibration is desired, the user manually adjusts the prime value K (step 938) by checking the image using the output device 30 and adjusting it using the input device 28. If manual calibration is not desired, the computing device 22 performs "an automatic" calibration as described above for Figure 10a (steps 940-945).

In a third exemplary embodiment of the method according to the present invention shown in Figure 10c, the system 100

is calibrated in another manner. In particular, after the external signal is detected (step 917), the external signal is converted into the digital signal (step 920). Then, instead of adjusting the amplification level of the sensor 1, the digital signal is adjusted as a function of the prime value K (step 925). In another alternative exemplary embodiment of the method according to the present invention, the system 100 includes the sensor 1 which has the controller 32, as described above. This controller 32 allows the manual calibration and/or automatic calibration of the system 100, with or without the computing device 22.

According to the present invention, a plurality of apparatuses may be connected to the RDU 18, e.g., the X-ray apparatus, the Infrared apparatus, the video apparatus and/or the audio apparatus. As described above, the audio apparatus may be positioned inside and/or outside of the system 100. Since of each of these four apparatuses transmits respective signals, the RDU 18 is capable to record each of such signals. Figure 11 shows an exemplary chart that allows the RDU 18 to determine from which apparatus is a received signal originated from using a predetermined binary code. In particular, each apparatus is assigned a predetermined binary code and a corresponding connector number. The RDU 18 interprets the signals from these apparatuses as a function of the predetermined binary codes and connector numbers (e.g., the X-ray apparatus has a binary code "00" and is assigned to XP1 connector) and forwards a corresponding message to the computing device 22 identifying a type of the signal being transmitted.

The RDU 18 may be situated in a close proximity to the patient. For example, the RDU 18 may be situated near a top portion of a dental chair as shown in Figure 1. An advantage of utilizing the RDU 18 in such manner is that a number of wires within a dental office can be reduced.

As discussed above, the system 100 may include the audio and video apparatuses. The video apparatus allows the system 100 to capture a video image while the audio apparatus allows

the system 100 to record comments from the user and/or the patient during the examination of the patient. The video and audio recordings are then converted into a digital form and linked to the image generated by the ESD 34. Thus, a single digital file may contain the ESD image and the video and audio recordings. This file may be maintained by the user, the patient or a predetermined databank.

One of the advantages of the present invention is that the patient's exposure to radiation (e.g., the X-ray radiation) is reduced by eliminating risk of unsatisfactory images due to a failure of the equipment or in an properly adjusted equipment. Thus, the image has a high resolution and clarity without risking image failures and unnecessary X-ray activations do not have to be performed.

Another advantage of the present invention is that the light concentrating element 9 (either on its own or together with the light reflective layer 7) strongly converges and concentrates the light beams from the crystal 5 to generate, using the particular layer 10, a crisp image with increased brightness, high resolution and clarity.

A further advantage of the present invention is that the retractable CRD 2 of the connecting plug 4 can be utilized. This CRD 2 avoids an irritation of the patient's mouth by the sensor 1. An absence of a long cable provides comfort by positioning the sensor 1 in the mouth without any hanging cords.

Another advantage of the present invention is that the controller 32 of the sensor 1 makes the system 100 faster and more reliable. In addition, the controller 32 frees the resources of the computing device 22 and simplifies an interface between the sensor 1, the RDU 18 and the computing unit 22.

Several exemplary embodiments of the present invention are specifically illustrated and/or described herein. However, it will be appreciated that modifications and variations of the present invention are covered by the above teachings and within the purview of the appended claims



without departing from the spirit and intended scope of the present invention.

WHAT IS CLAIMED IS:

1. A system for providing a dental diagnosis, comprising:  
an external signal device generating an external signal;  
and

a sensor including an arrangement, a light concentrating element, a particular layer and an electronic circuitry, the arrangement receiving the external signal and converting the external signal into a light beam, the light concentrating element concentrating the light beam, the particular layer receiving the concentrated light beam and converting the concentrated light beam into an analog signal, the electronic circuitry converting the analog signal into a digital signal, the digital signal providing data for the dental diagnosis.

2. The system according to claim 1, further comprising:  
a computing device including a memory unit which stores predetermined variables and a processing unit which processes the predetermined variable and the digital signal; and  
a remote unit coupled between the sensor and the computing device.

3. The system according to claim 2, wherein the remote unit is a remote digital unit.

4. The system according to claim 2, wherein the sensor is coupled to at least one of the remote unit and the computing device via at least one of a wireless arrangement and a wired arrangement.

5. The system according to claim 2, wherein the remote unit is positioned in a close proximity to a user.

6. The system according to claim 2, wherein the remote unit is positioned in at least one of a chair and a head rest of the chair.

7. The system according to claim 2, wherein the digital signal is provided to the computing device via the remote unit.
8. The system according to claim 1, further comprising:  
a recording apparatus recording at least one of a video signal and an audio signal, wherein the video and audio signals are associated with the data corresponding to the digital signal.
9. The system according to claim 1, wherein the external signal device includes at least one of an X-ray apparatus and an Infrared apparatus.
10. The system according to claim 1, further comprising:  
an output device outputting an image indicative of the digital signal.
11. The system according to claim 1, wherein the sensor includes at least one internal light device for calibrating the sensor.
12. The system according to claim 1, wherein the particular layer includes at least one of a charge coupled device ("CCD") and a complementary metal-oxide semiconductor ("CMOS") array.
13. The system according to claim 1, wherein the light concentrating element includes a lens.
14. The system according to claim 1, wherein the system is an element of arrangements which are coupled together to form a network.
15. The system according to claim 14, wherein the network is connected to a communication network.
16. An intra-oral sensor for providing a dental diagnosis,

comprising:

an arrangement receiving an external signal and converting the external signal into a light beam;

a light concentrating element concentrating the light beam;

a particular layer receiving the concentrated light beam and converting the concentrated light beam into an analog signal; and

an electronic circuitry converting the analog signal into a digital signal, the digital signal providing data for the dental diagnosis.

17. The system according to claim 16, wherein the light concentrating element includes a lens.

18. The system according to claim 16, wherein the particular layer includes at least one of a charge coupled device ("CCD") and a complementary metal-oxide semiconductor ("CMOS") array.

19. The intra-oral sensor according to claim 16, further comprising:

a connector connecting the intra-oral sensor to at least one of a computing device and a remote unit, the connector including a cable and a cable housing, wherein a length of the cable is adjusted within the cable housing.

20. The intra-oral sensor according to claim 16, further comprising:

a housing including a top portion, wherein the first signal are received only in the top portion of the housing, the housing enclosing the arrangement, the light concentrating element, the particular layer and the electronic circuitry.

21. The intra-oral sensor according to claim 20, further comprising:

a case enclosing the housing.

22. The intra-oral sensor according to claim 16, further comprising:

at least one internal light device arranged in the arrangement and generating a further light beam for calibrating the intra-oral sensor.

23. The intra-oral sensor according to claim 22, wherein the light concentrating element concentrates the further light beam into a further concentrated light beam, the further concentrated light being converted into the analog signal using the particular layer.

24. The intra-oral sensor according to claim 16 further comprising:

at least one coating provided on an outer periphery of the intra-oral sensor.

25. The intra-oral sensor according to claim 24, wherein the at least one coating includes four coatings, each of the four coatings positioned on a respective corner of the intra-oral sensor.

26. The intra-oral sensor according to claim 24, wherein the at least one coating is composed of at least one of a soft material, a self-sterilized material and an anti-microbial material.

27. The intra-oral sensor according to claim 21, further comprising:

a light reflective layer situated on an internal side of the top portion of the housing.

28. The intra-oral sensor according to claim 27, wherein the light reflective layer allows the external signal to enter the housing and prevents the light beam from exiting the housing.

29. The intra-oral sensor according to claim 27, wherein the



light reflective layer and the light concentrating element concentrates the light beam into the concentrated light beam.

30. The intra-oral sensor according to claim 16, wherein the electronic circuitry includes a memory unit, an amplifier, a comparator and a converter, the memory unit storing a reference level and a correction value, the amplifier adjusting an amplification level of the analog signal, the comparator comparing a first value of the reference level to a second value of the digital signal, the converter converting the analog signal into the digital signal and the digital signal into the analog signal.

31. The intra-oral sensor according to claim 30, wherein the amplifier includes a programmable amplifier.

32. The intra-oral sensor according to claim 30, wherein the electronic circuitry further includes a wireless arrangement transmitting the digital signal to a further arrangement which receives the digital signal.

33. The intra-oral sensor according to claim 30, wherein the electronic circuitry further includes a controller processing the digital signal.

34. The intra-oral sensor according to claim 16, wherein the light concentrating element has at least one of a flat shape and a flat-convex shape.

35. The intra-oral sensor according to claim 34, wherein, when the light concentrating element has the flat shape, the light concentrating element including a concentric surface and having a stepped shape.

36. The intra-oral sensor according to claim 16, wherein the arrangement includes one of a scintillator and a thermo-illuminator.

37. The intra-oral sensor according to claim 16, wherein the intra-oral sensor has at least one of a flat-convex shape, a rectangular shape, a circular shape, an oval shape and a square shape.

38. The intra-oral sensor according to claim 21, further comprising:

a disposable arrangement covering the case, the disposable arrangement being composed of at least one of a plastic sheath and a disposable latex coating.

39. The intra-oral sensor according to claim 21, wherein the case is composed of a force-absorbing material, and wherein an edge-portion of the case is composed of a sponge material.

40. The intra-oral sensor according to claim 16, wherein the sensor is coupled to at least one of a computing unit and a remote unit via at least one of a wireless arrangement and a wired arrangement.

41. A method for providing a dental diagnosis, comprising the steps of:

(a) activating an internal light device to generate a light signal;

(b) adjusting an amplification level of an amplifier of an intra-oral sensor as a function of a predetermined correction value;

(c) detecting the light signal;

(d) converting the light signal into a digital signal as a function of the adjusted amplification level; and

(e) if the internal light device is activated, executing the following steps:

if a signal value of the digital signal is not equal to a predetermined reference level, modifying the predetermined correction value as a function of the predetermined reference level and the signal value, and

repeating steps (b) - (e) until the signal value is equal to the predetermined reference level, wherein the digital signal provides data for the dental diagnosis.

42. The method according to claim 41, wherein, in step (c), the light signal is detected using a particular layer of the intra-oral sensor.

43. The intra-oral sensor according to claim 42, wherein the particular layer includes a charge coupled device ("CCD") or a complementary metal-oxide semiconductor ("CMOS") array.

44. The method according to claim 41, further comprising the step of:

(f) manually adjusting the predetermined correction value.

45. The method according to claim 41, wherein step (d) includes the substep of manually adjusting the predetermined correction value.

46. The method according to claim 41, wherein step (d) includes the substep of manually adjusting the amplification level.

47. The method according to claim 41, wherein step (e) includes the substep of at least one of displaying an image indicative of the digital signal and storing the image in a memory unit.

48. The method according to claim 41, further comprising the steps of:

(g) deactivating the internal light device and activating an external signal device which generates the light signal;

(h) further adjusting the amplification level as a function of the predetermined correction value;

(i) detecting a further light signal generated by the external signal device;

(g) converting the further light signal into the digital signal as a function of the adjusted amplification level; and

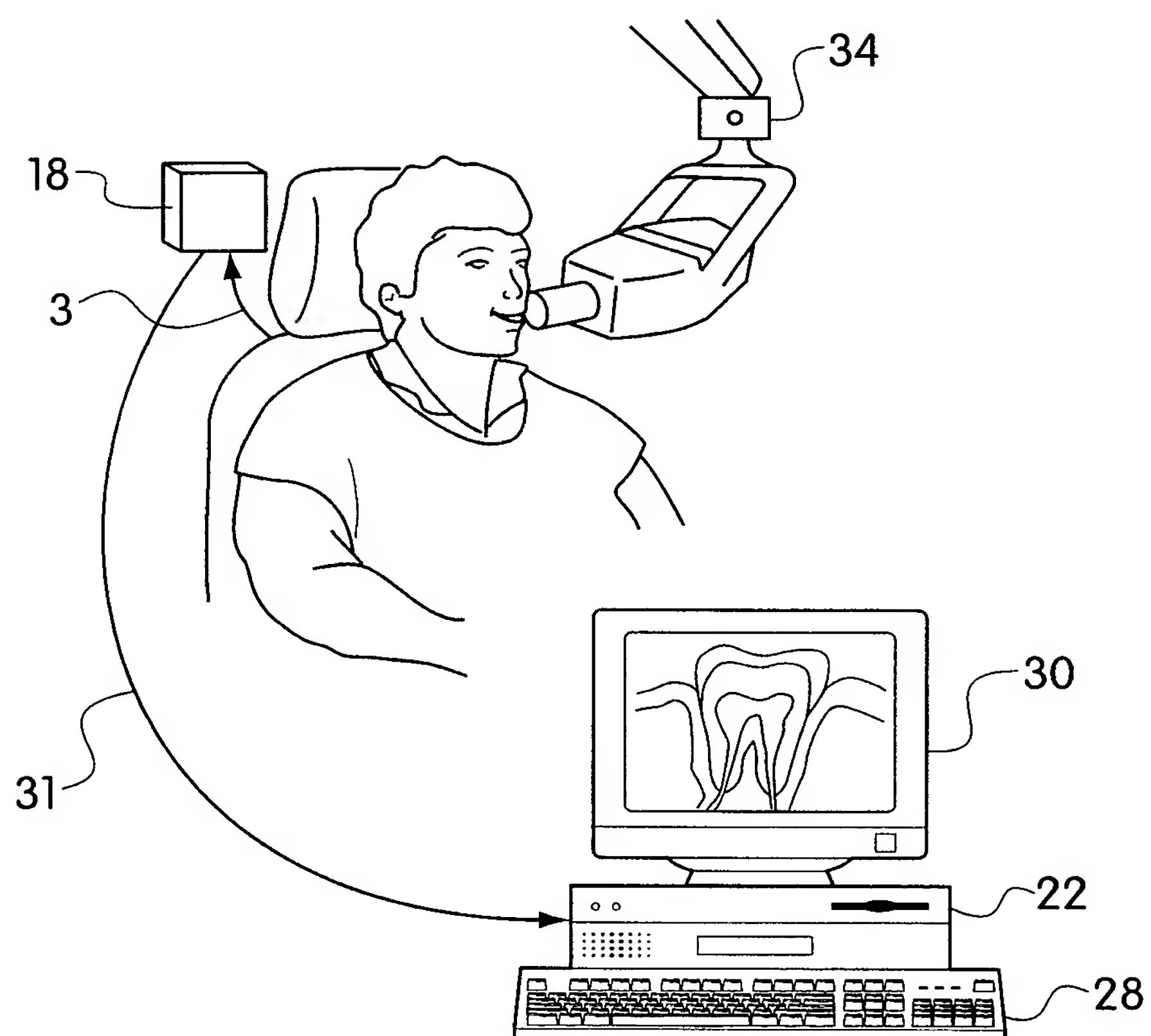
(k) at least one of displaying and storing an image indicative of the digital signal.

49. The method according to claim 48, further comprising the step of:

(m) adjusting the digital signal as a function of the predetermined correction value.

50. The method according to claim 48, wherein in step (i), the light signal is detected using an intra-oral sensor.

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**FIG. 1**



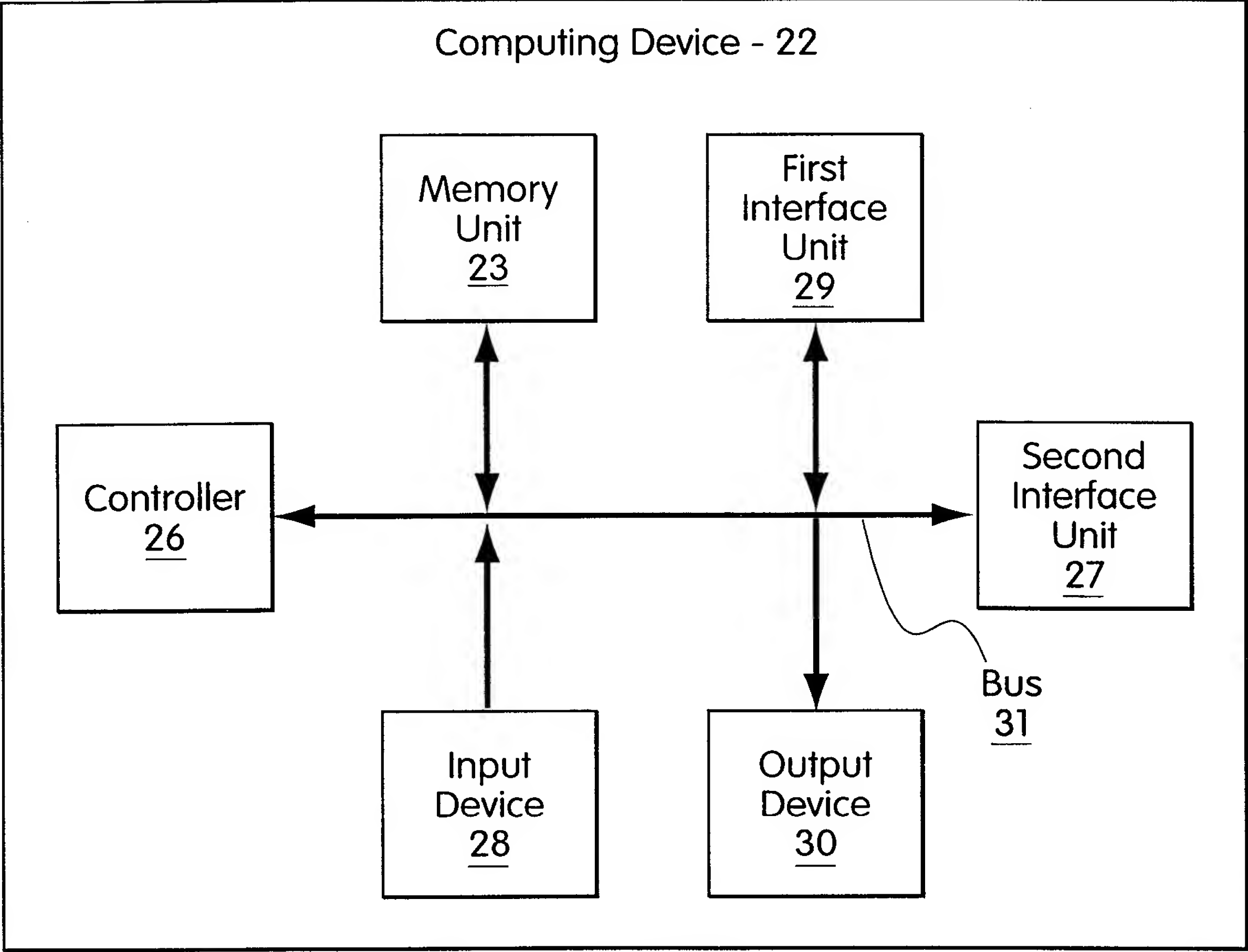


FIG. 2

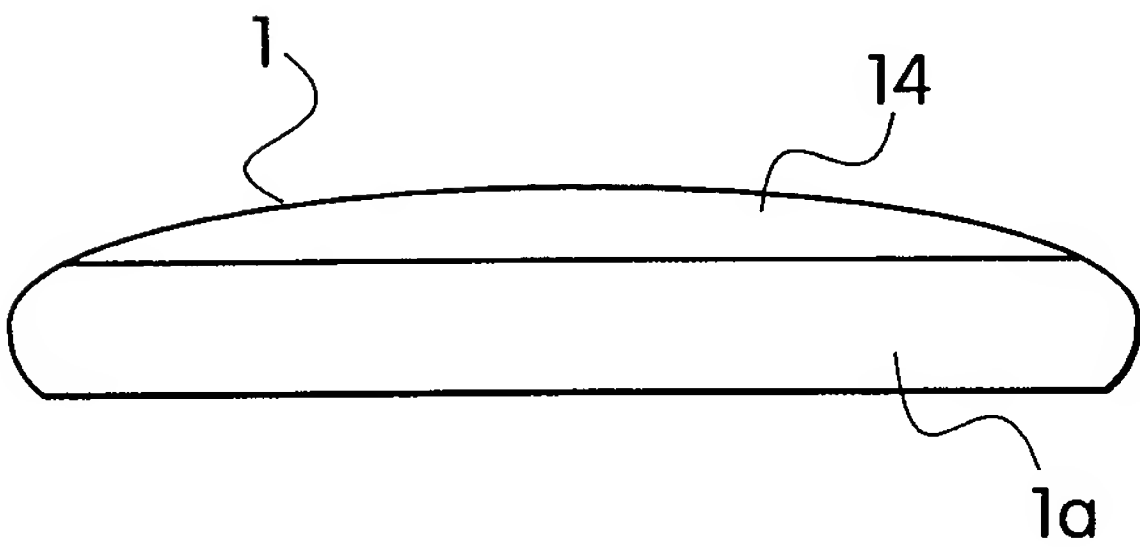
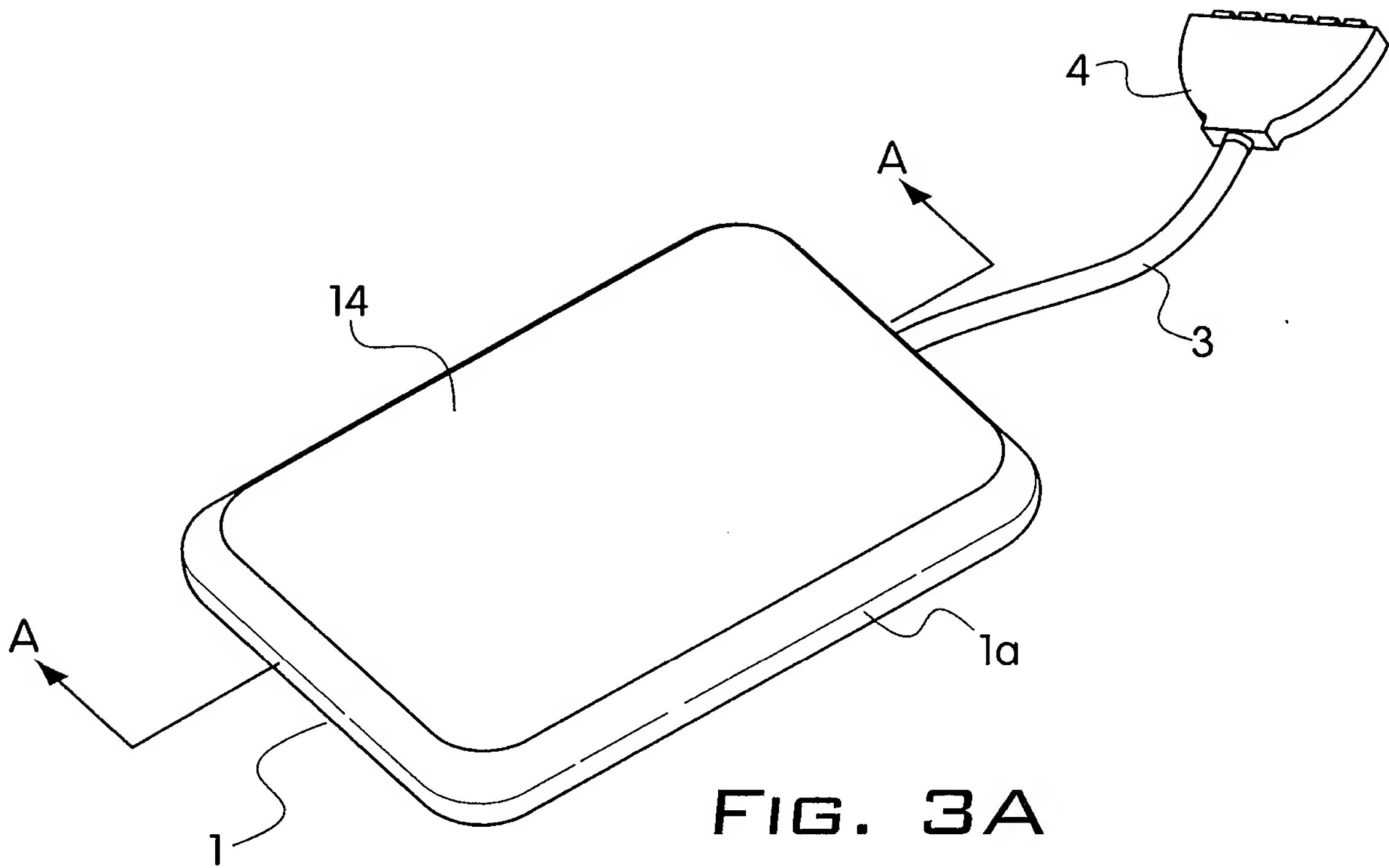


FIG. 3B

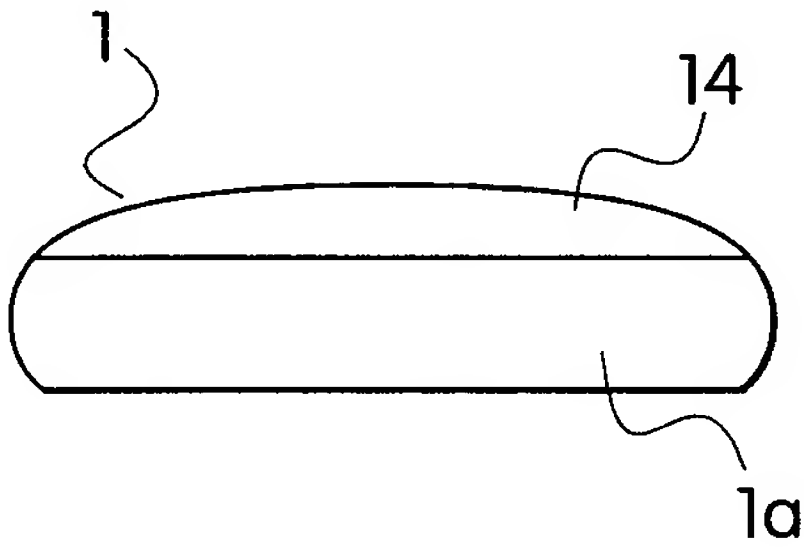
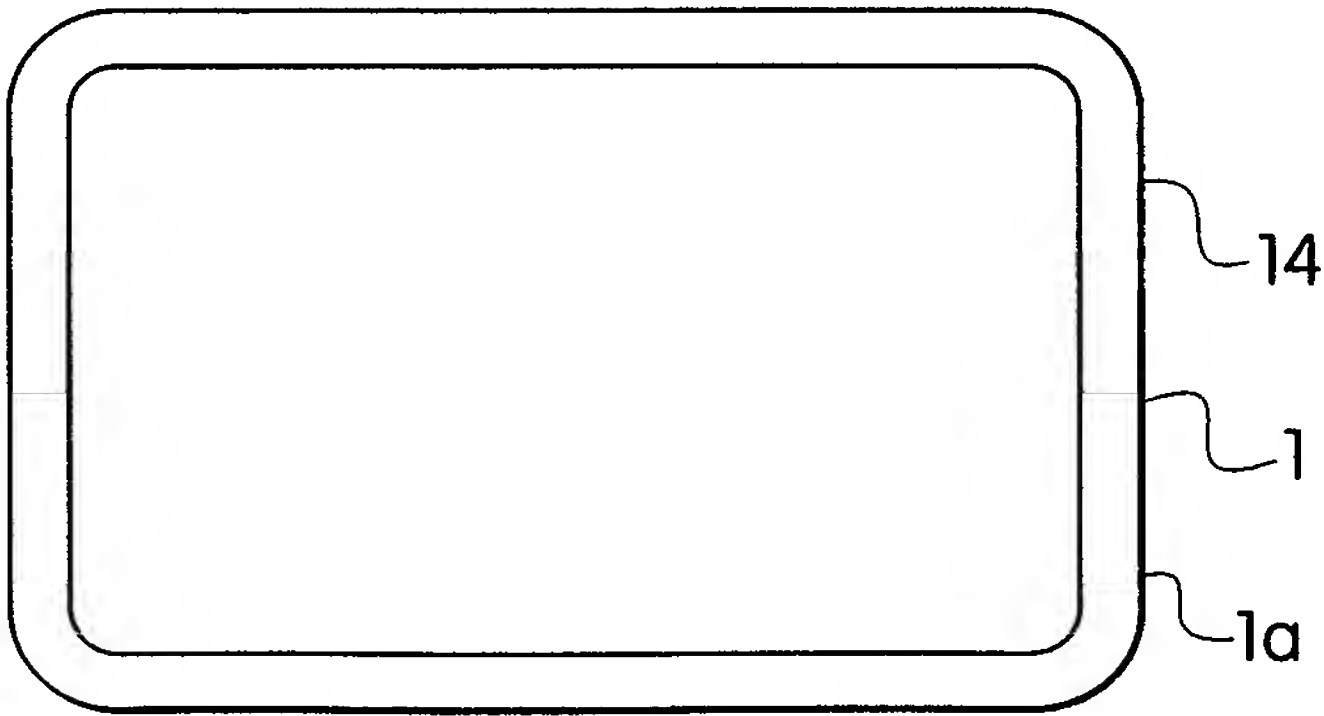
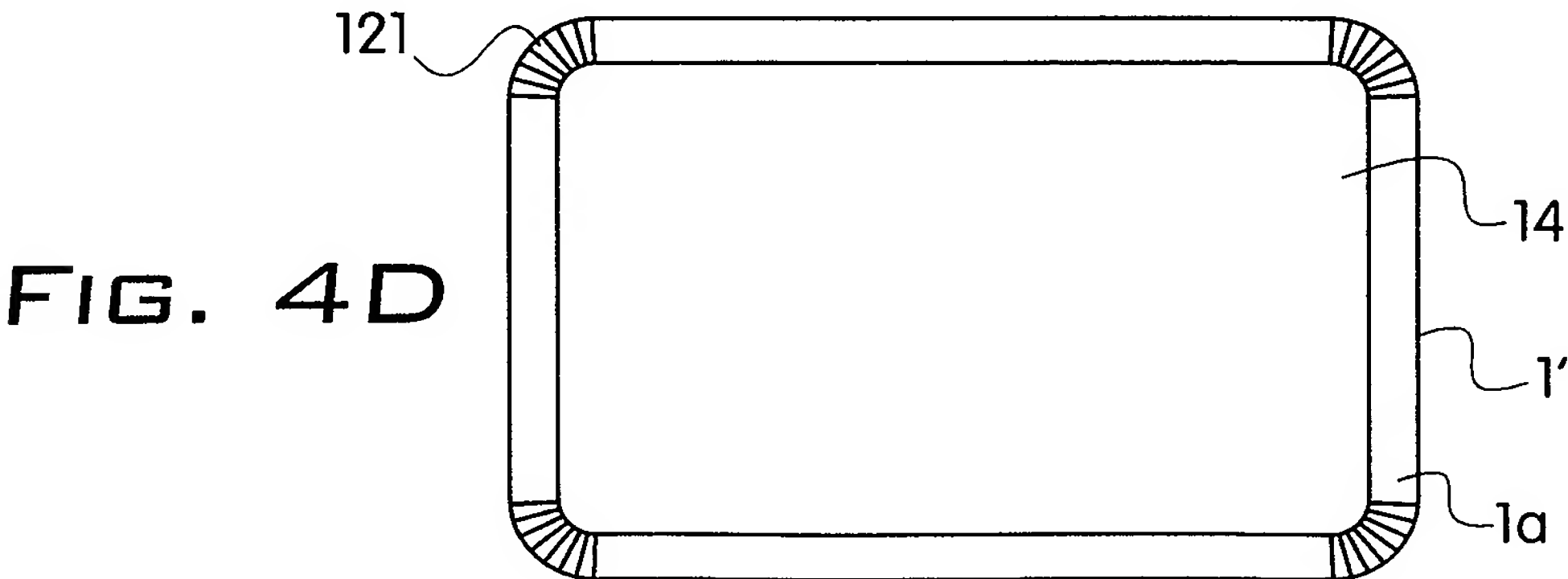
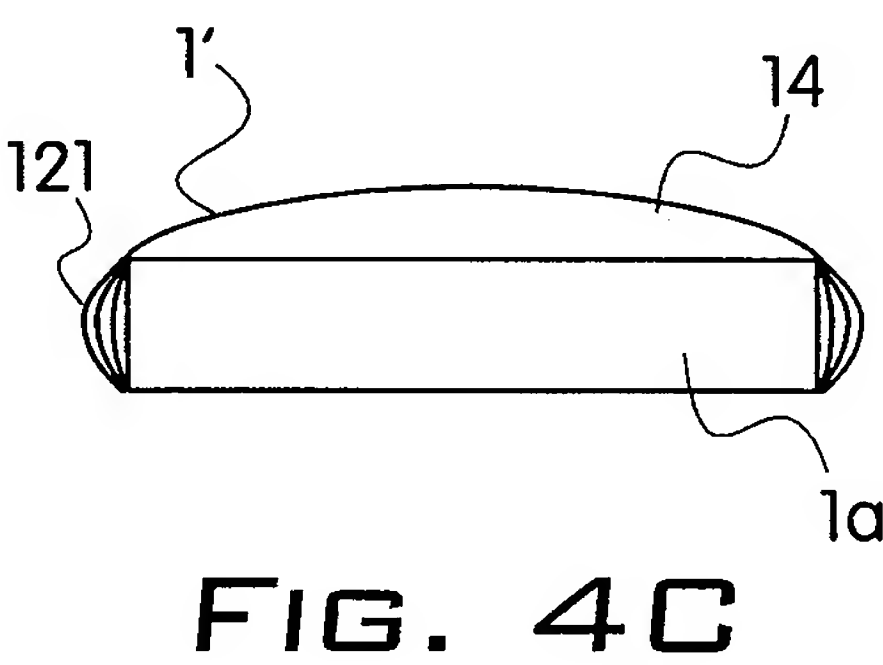
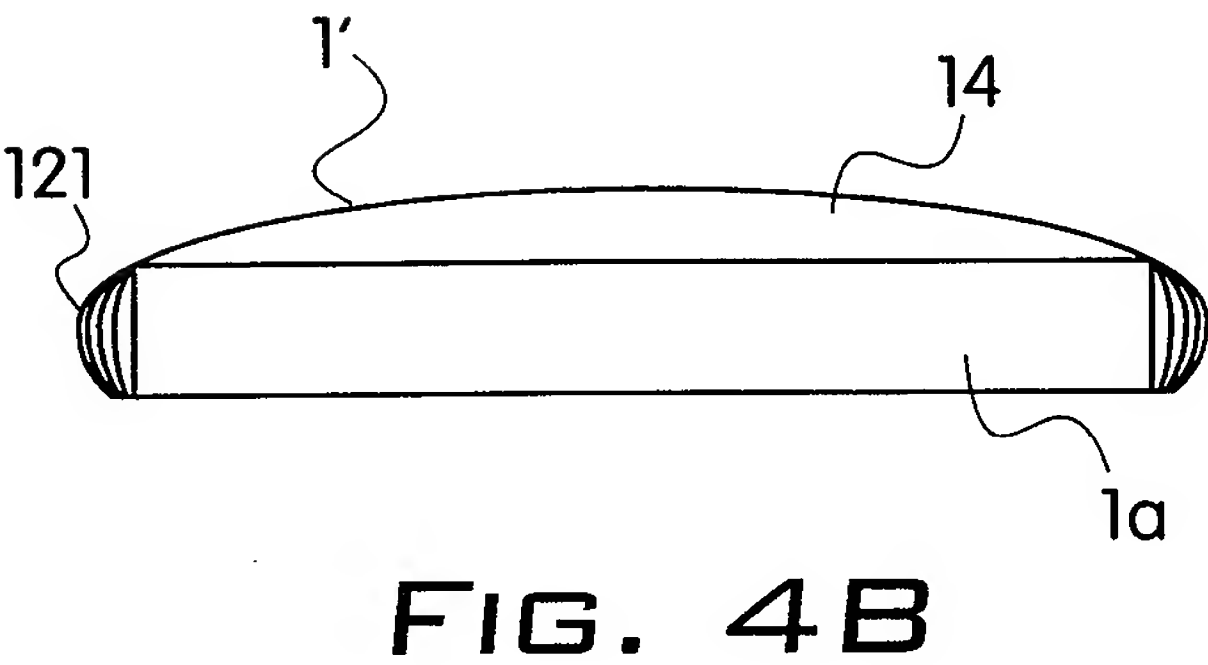
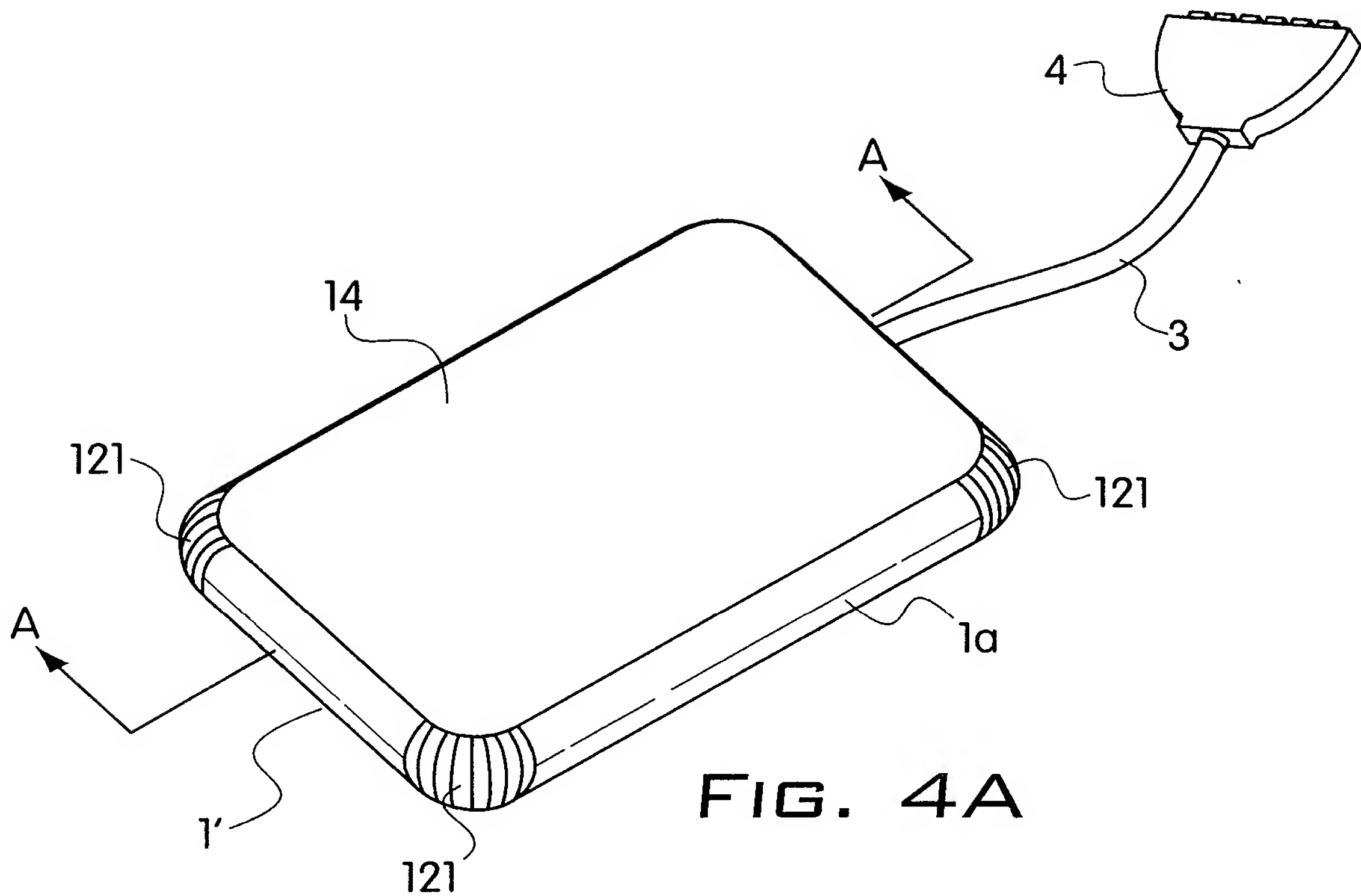


FIG. 3C

FIG. 3D





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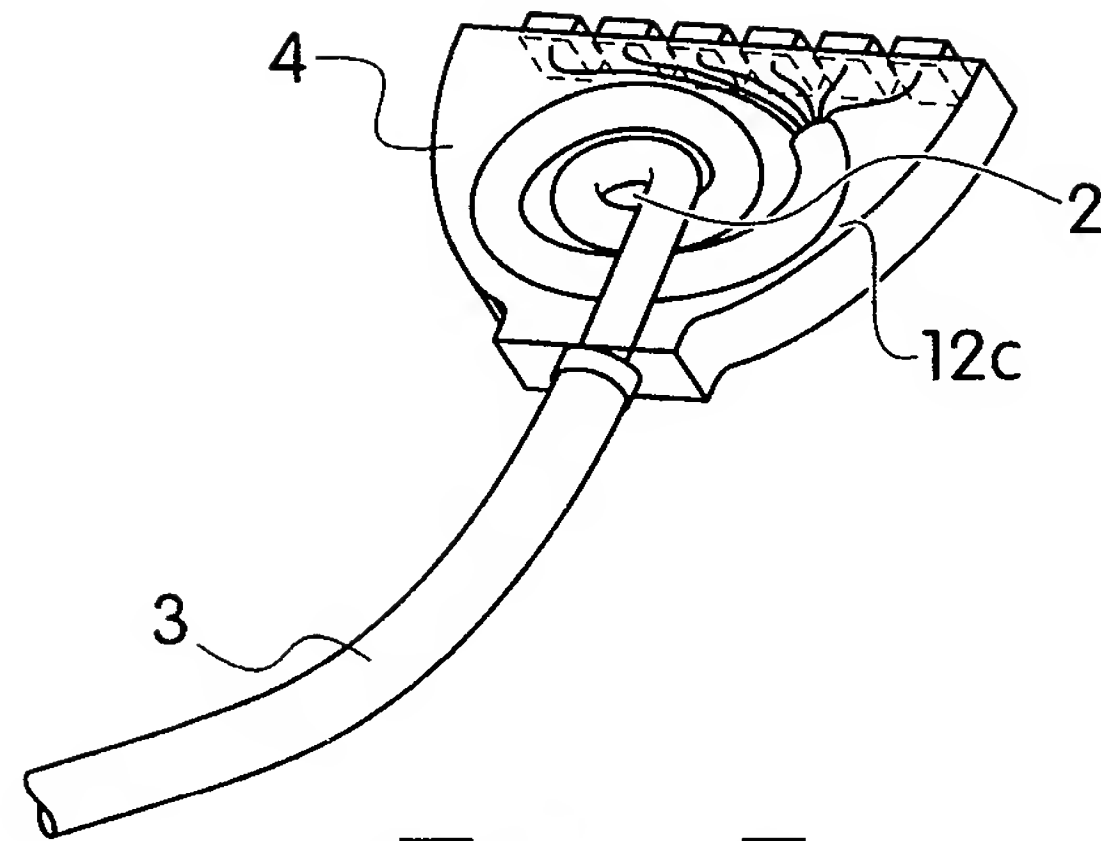


FIG. 5

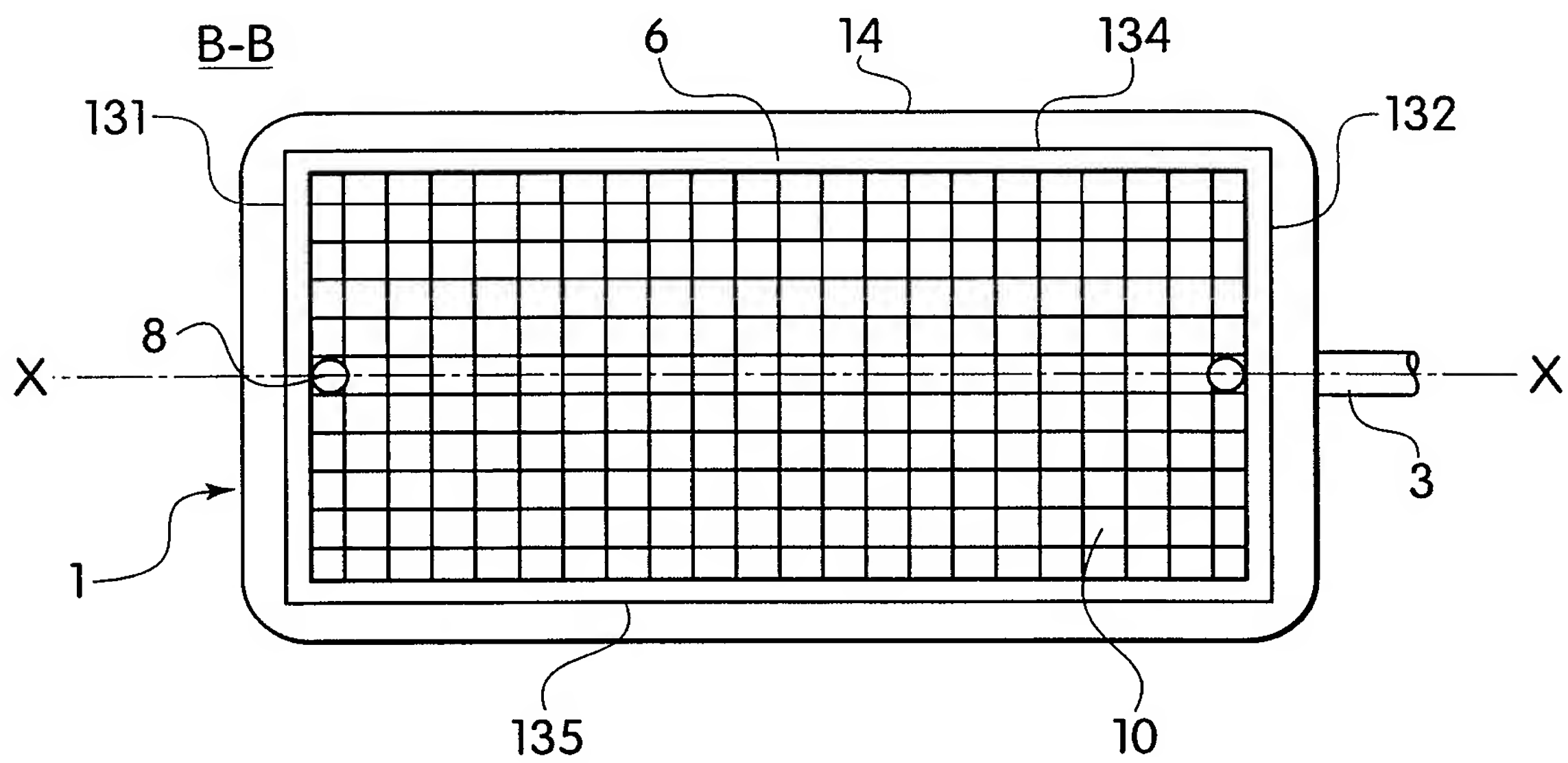
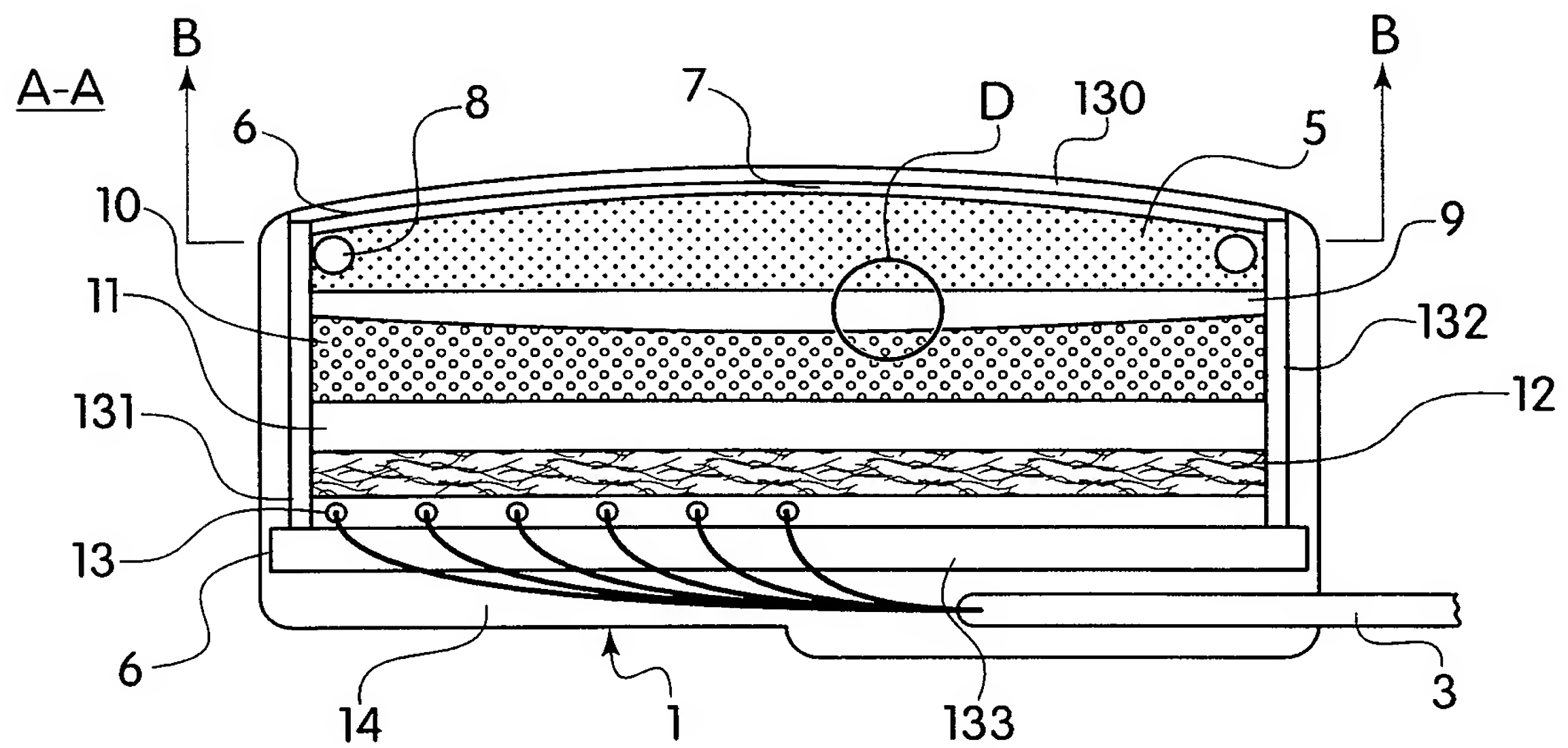
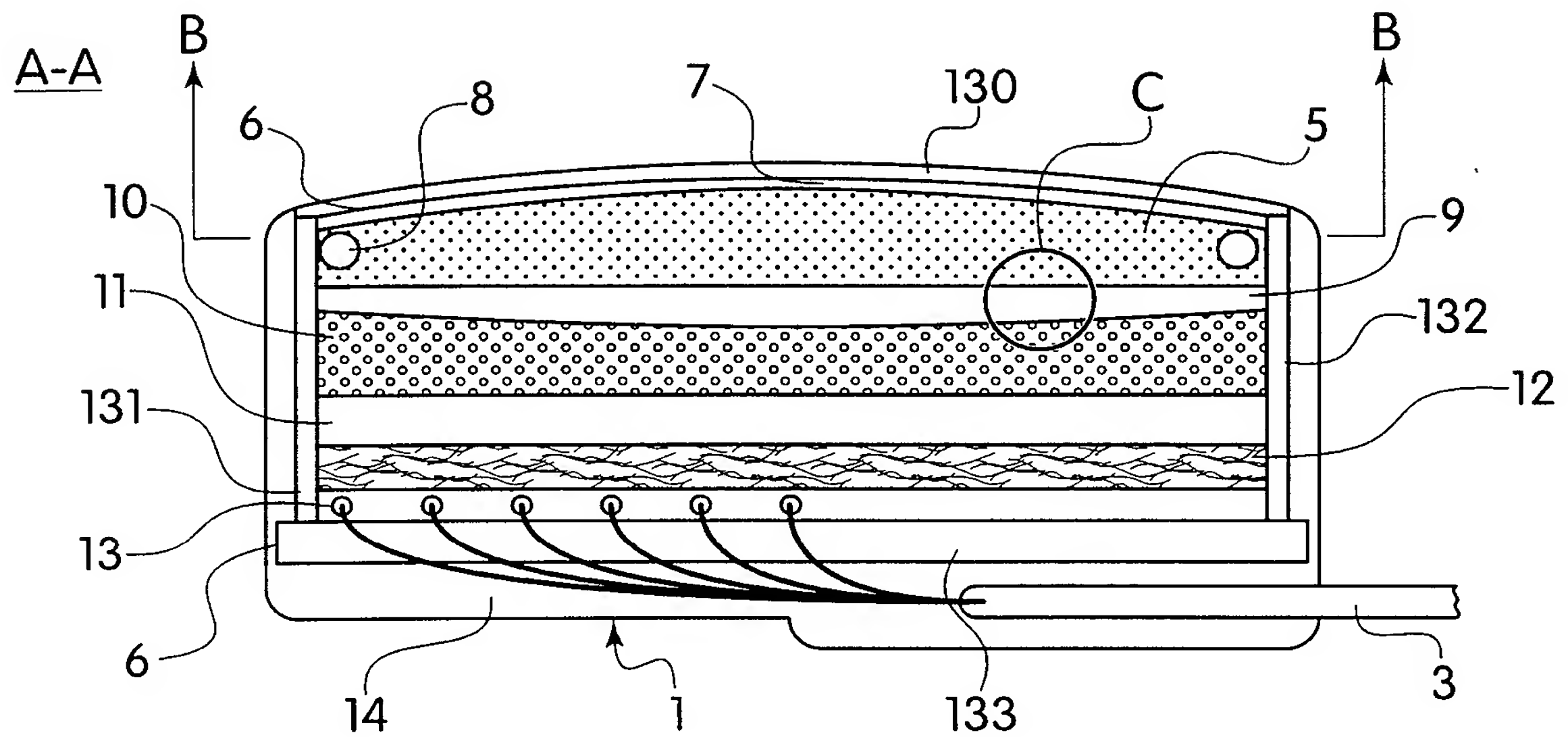


FIG. 8

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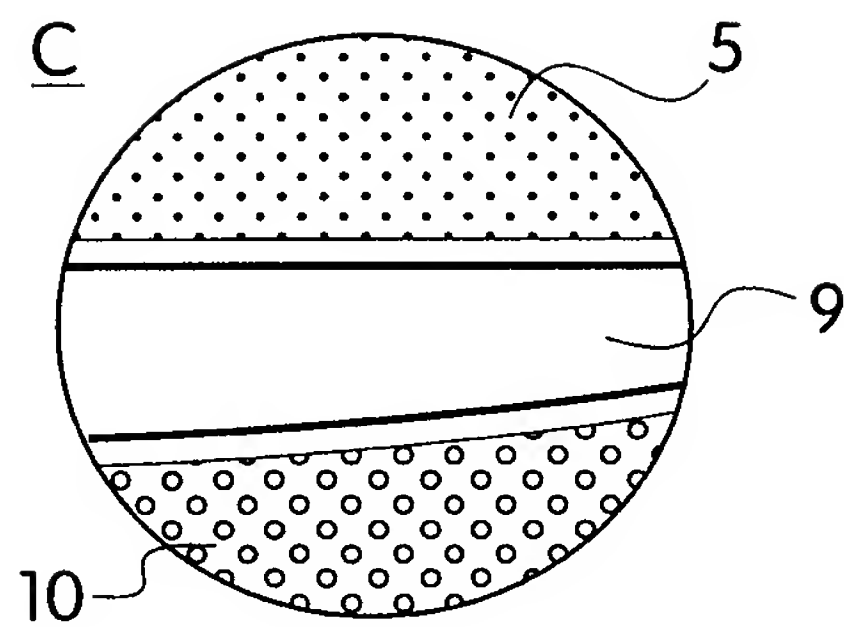


FIG. 7A

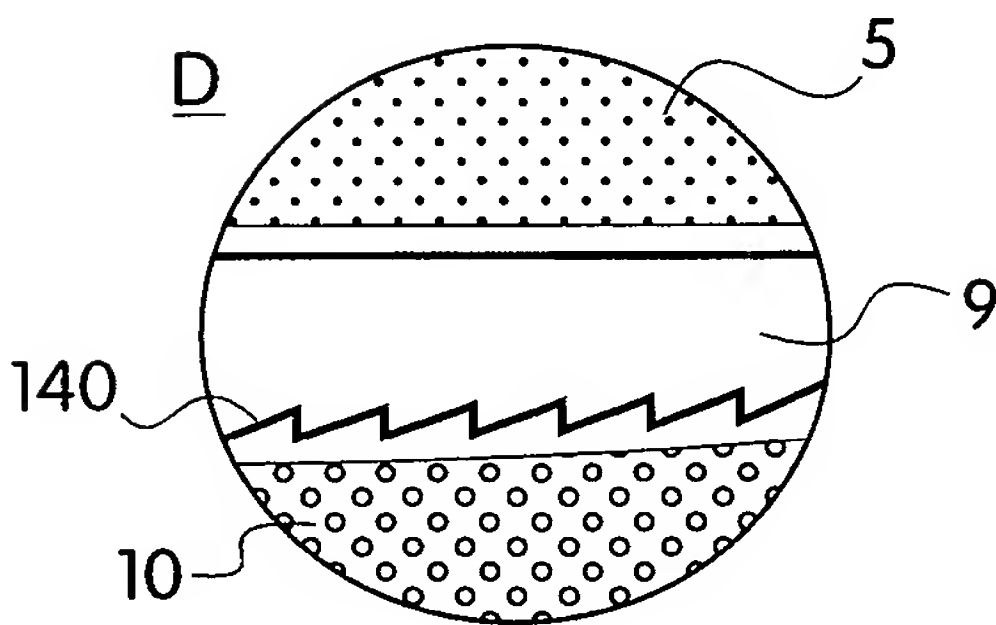
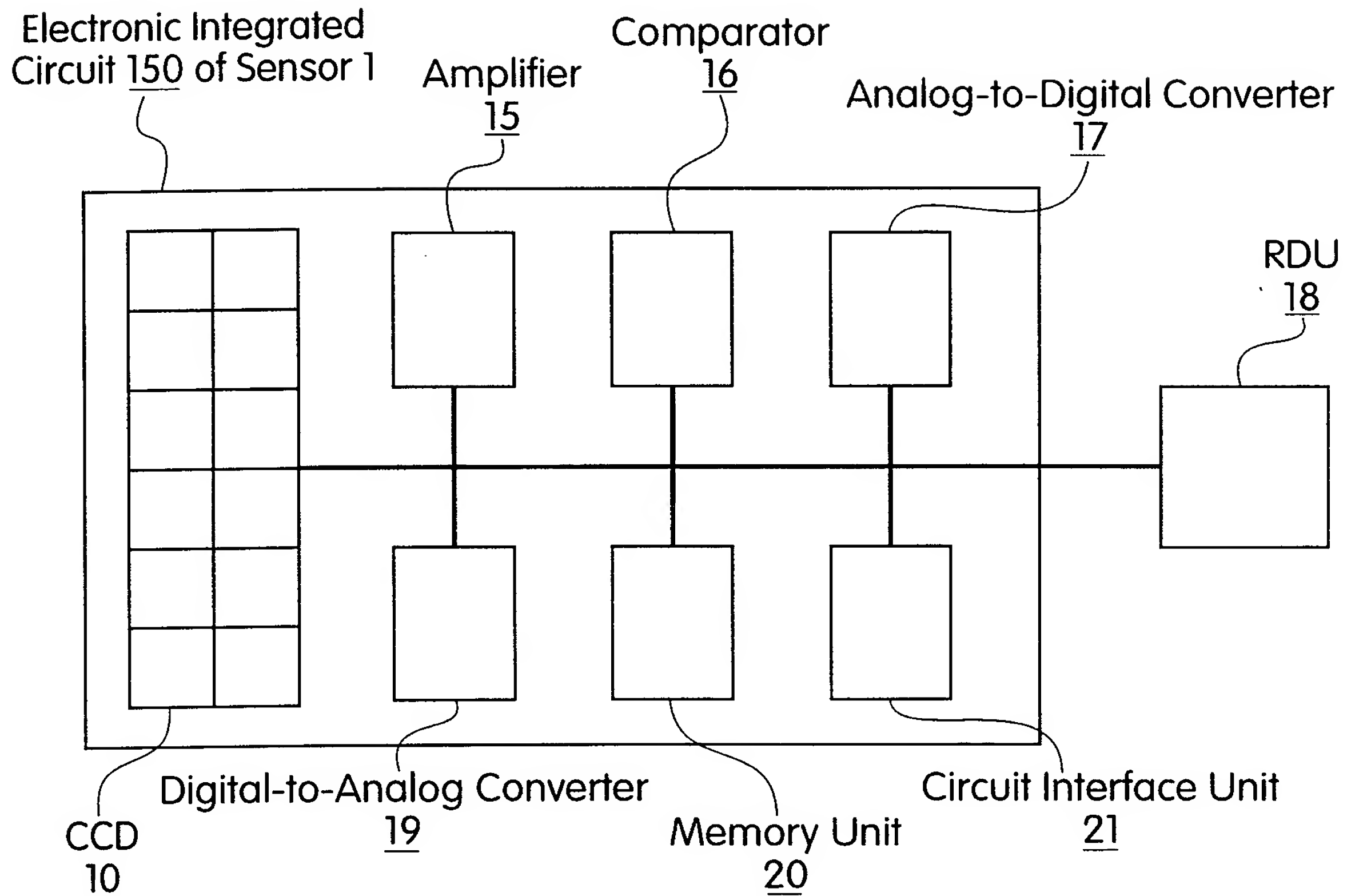
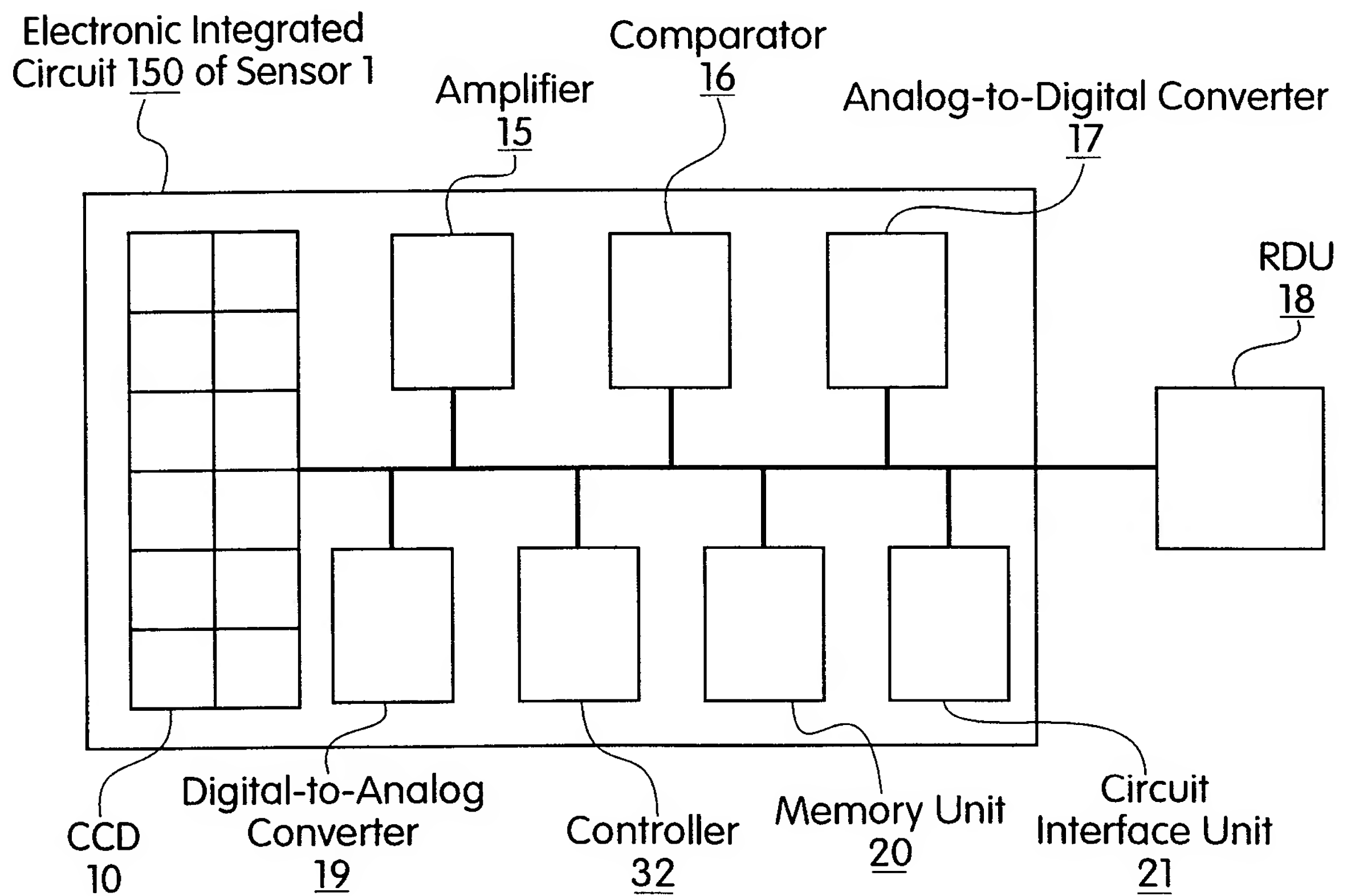


FIG. 7B

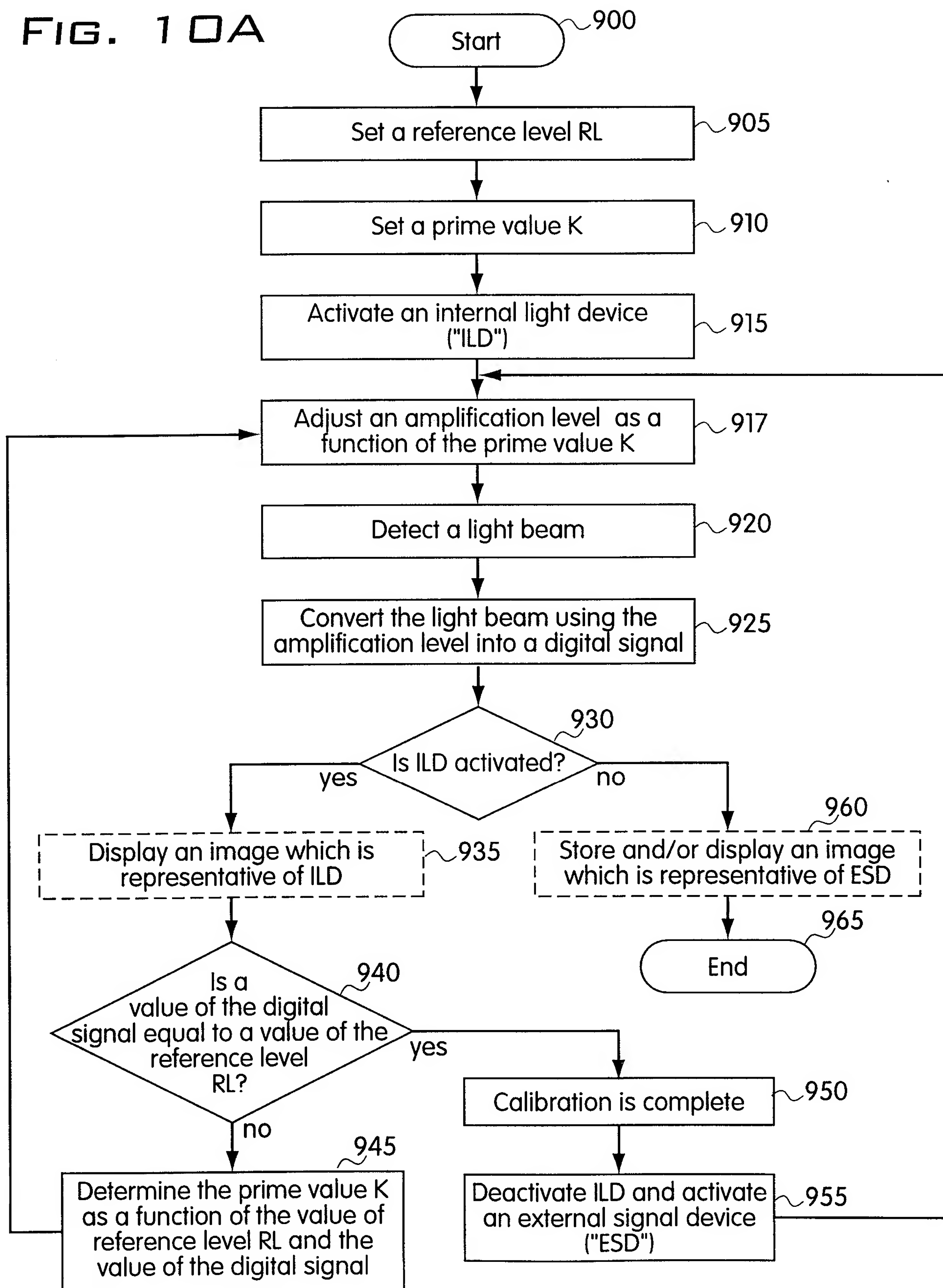


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**FIG. 9A****FIG. 9B**

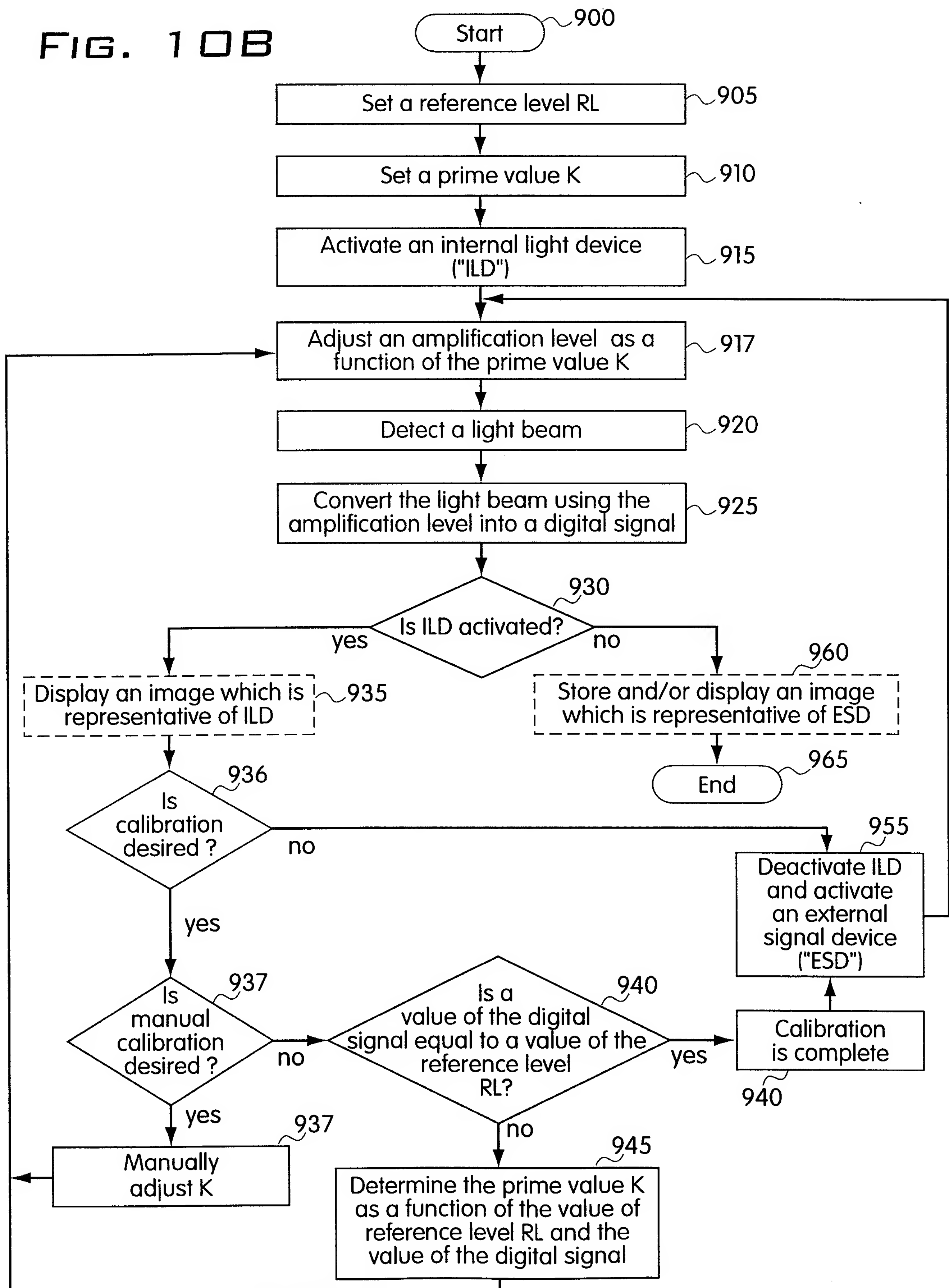
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FIG. 10A



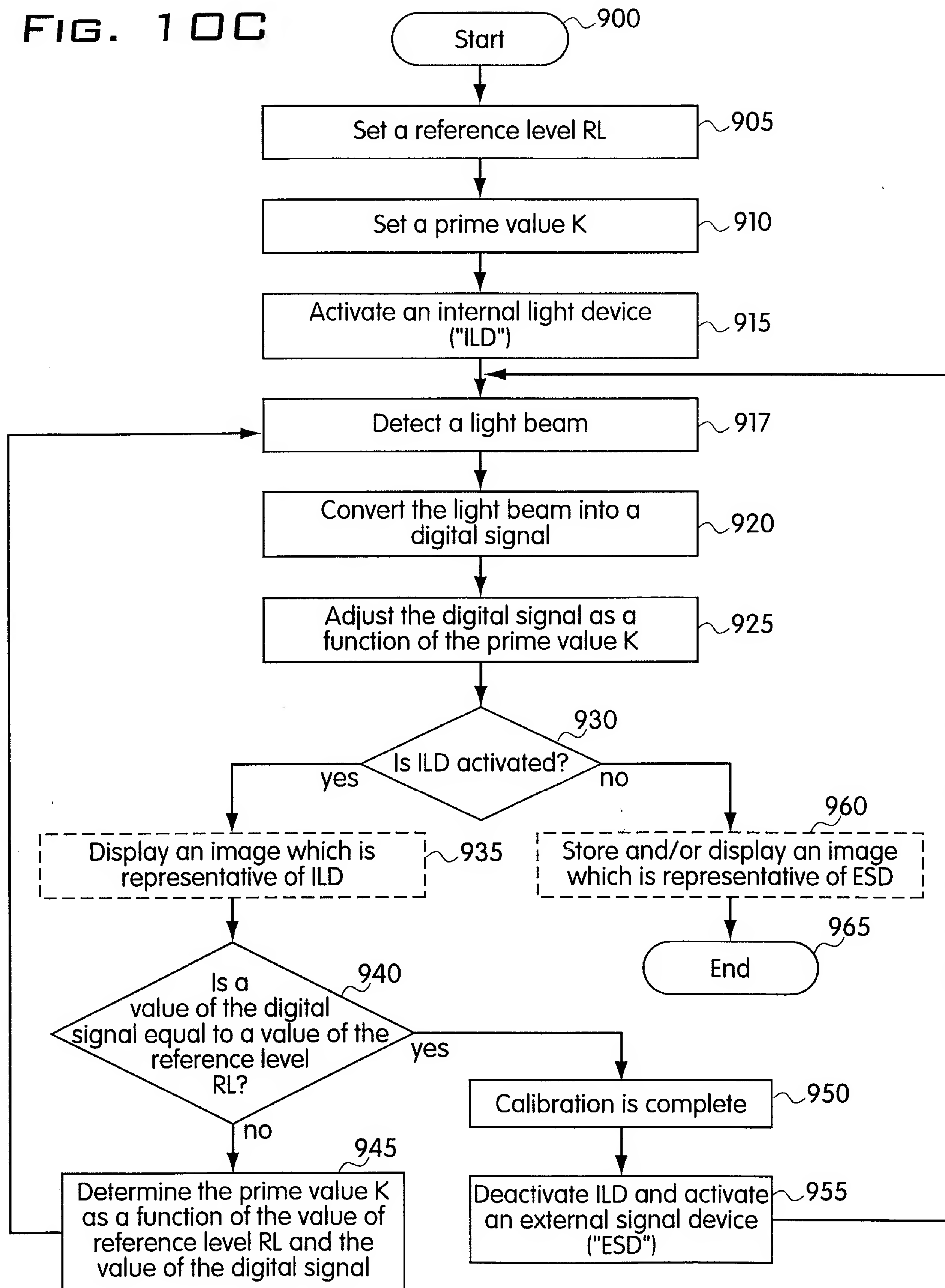
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FIG. 10B



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FIG. 100



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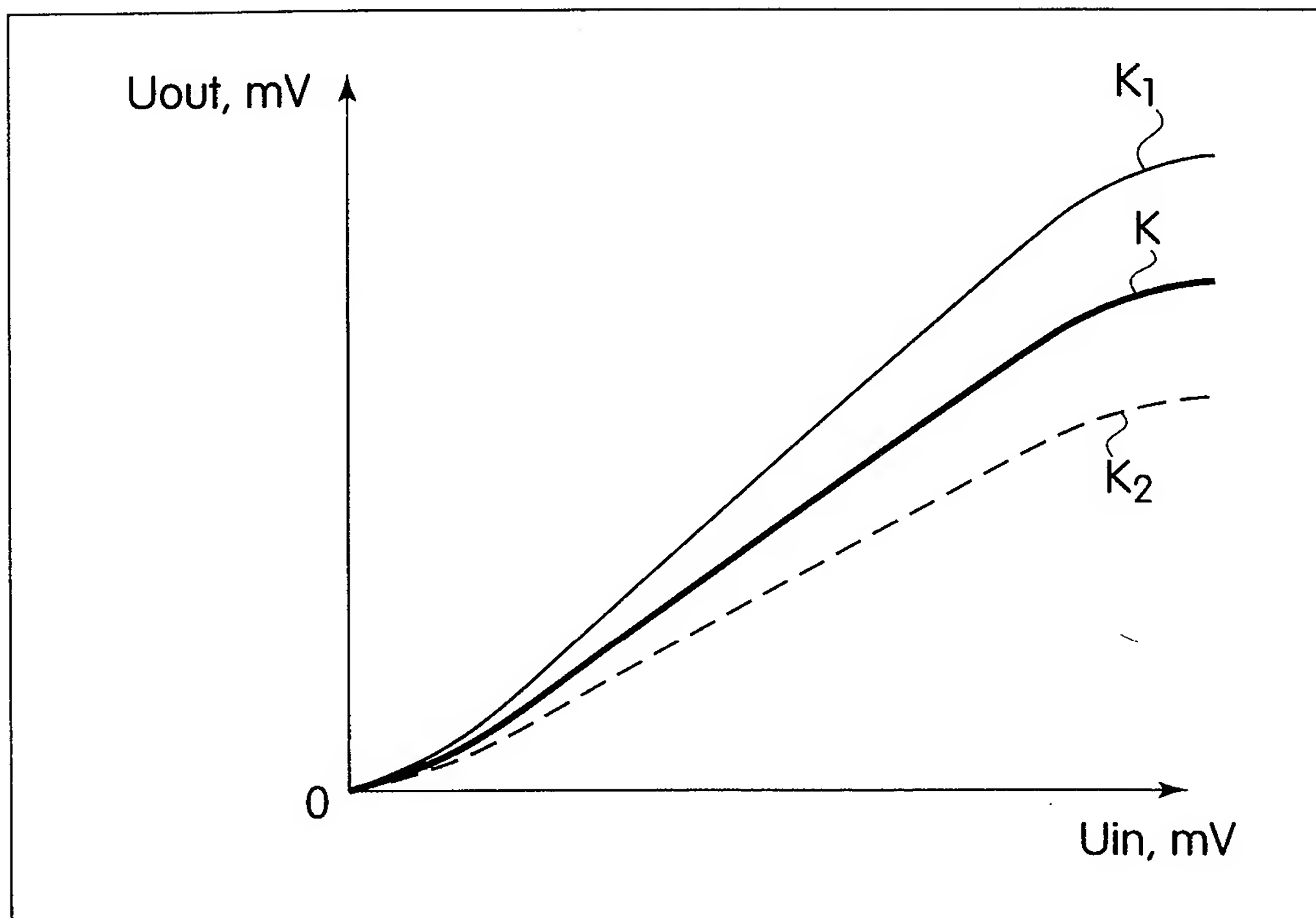


FIG. 1 1 A

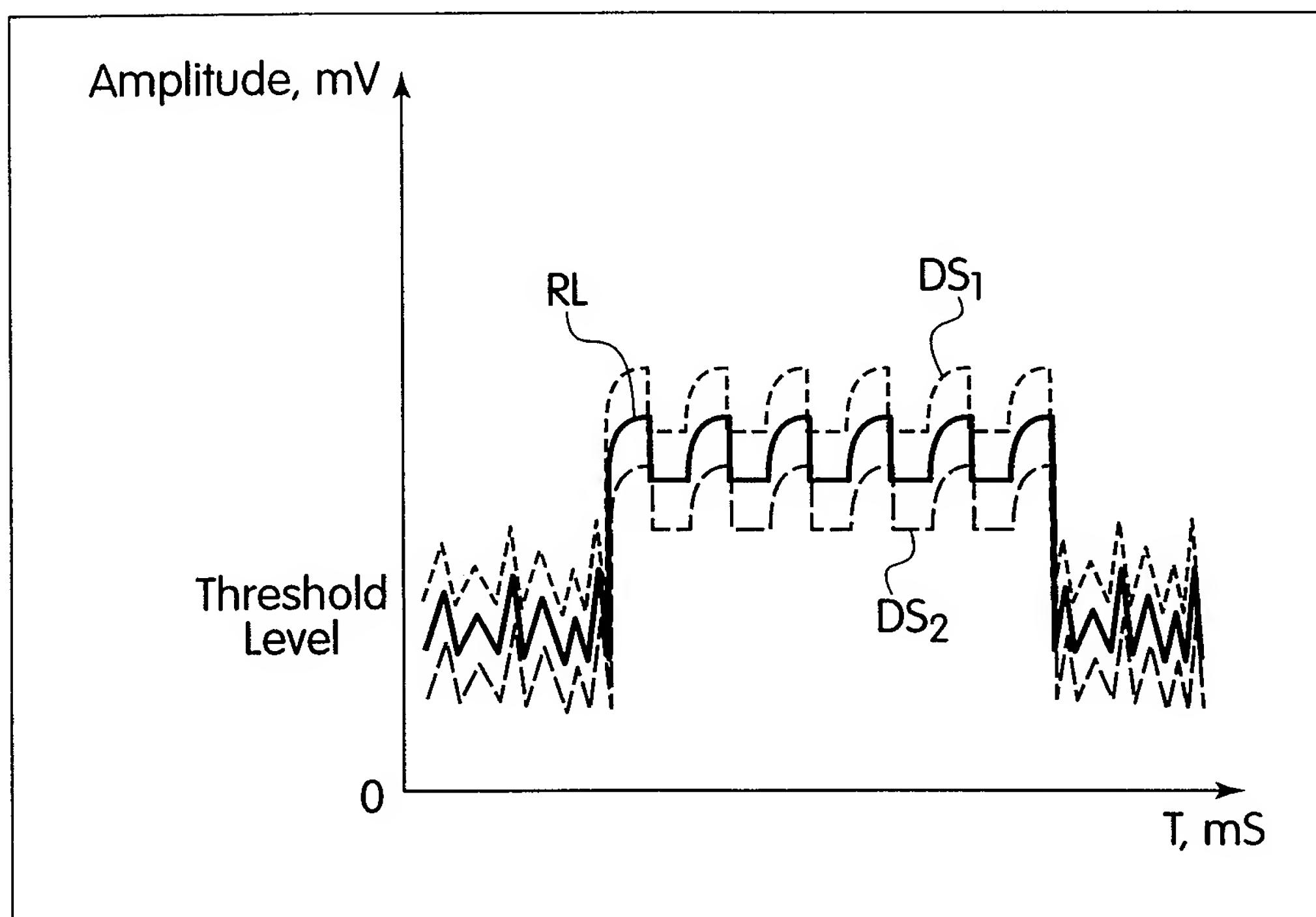


FIG. 1 1 B

Binary Code	Connector	Apparatus
00	XP1	X-ray apparatus
01	XP2	Infrared apparatus
10	XP3	Video apparatus
11	XP4	Audio apparatus

FIG. 12



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US99/27104

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(7) :GO1T 1/20

US CL :250/370.11

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 250/370.11, 370.09, 370.07, 370.06; 378/368, 97, 38

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

USPTO EAST

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X; Y	US 5,331,166 A (YAMAMOTO ET AL) 19 JULY 1994 (19/07/94), SEE ENTIRE DOCUMENT.	1-40; 41-50
Y	US 5,237,173 A (STARK ET AL) 17 AUGUST 1993 (17/08/93), SEE ENTIRE DOCUMENT.	41-50



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
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"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

16 MARCH 2000

Date of mailing of the international search report

04 APR 2000

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